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| Date | Reference | Page |
|---|---|---|
| 2018-03-16 | P17-0042-2 rev 1 | 1 (46) |

Moises Pacheco
Shape Robotics APS
Linde Alle 29 A
2850 Nærum
Denmark

DANAK
TEST Reg.nr. 563

FCC Designation
Number: DK0002

# Test Report

of

Dongle DNG002
FCC ID: 2AOUEDNG002
according to

FCC 47 CFR, Part 15 Subpart C
15.249 Operation within the band 2400 - 2483.5 MHz

**EKTOS Testing & Reliability Services A/S**

Performed by

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| | | | |
|---|---|---|---|
| **Report no.:** | P17-0042-2 rev 1 | **Report date:** | 2018-03-16 |
| **Test started:** | 2018-01-19 | **Test ended:** | 2018-03-14 |
| **Number of pages:** | 46 | **Client contact:** | Moises Pacheco |

| | | | |
|---|---|---|---|
| **Test laboratory:** | EKTOS TRS A/S<br>A. C. Meyers Vænge 15<br>2450 Copenhagen SV<br>Denmark | **Client:** | Shape Robotics APS<br>Linde Alle 29 A<br>2850 Nærum<br>Denmark |

| | |
|---|---|
| **Facility reg. no.** | FCC Designation number: DK0002 |
| **Test specimen:** | Dongle Model No: DNG002. FCC ID: 2AOUEDNG002 |
| **Test specification:** | FCC 47 CFR Part 15 Subpart C<br>15.249 Operation within the band 2400 - 2483.5 MHz<br>The tests relevant for the test specimens are listed in *section 1.1*. |
| **Documentation:** | P17-0042-2 rev 1 supersedes P17-0042-2 issued 2018-02-20.<br>Changes: Duty cycle measurements repeated and Duty cycle correction factor used to demonstrate compliance with average limits.<br><br>This test report must always be reproduced in full; reproduction of an excerpt only is subject to written approval of the testing laboratory.<br><br>The complete test documentation is archived for 10 years at the testing laboratory. |
| **Test results:** | The test specimen complies with relevant parts of the test specifications.<br><br>The test results relate only to the specimen tested. |
| **Test personnel:** | Søren Søltoft Ruben Hansen |

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## Appendix

1 Photos

# 1 SUMMARY

See Appendix 1 for photos.
Emission measurements as specified below have been performed.

## 1.1 Test plan

| Standard | Name of the test | Results |
|---|---|---|
| FCC 47 CFR Part 15C | 15.249 Operation within the band 2400-2483.5 MHz | PASSED |
| 15.35 (c) | Duty cycle measurement | - |
| 15.249 (a) | Field strength of fundamental | PASSED |
| 15.249 (d) (e) | Radiated emission | PASSED |
| 15.207 | AC conducted emission | PASSED |
| 15.215 (c) | 20 dB bandwidth | PASSED |
| 2.1049 | Occupied bandwidth | PASSED |
| 2.1049 | Band Edge | PASSED |

PASSED The test was performed and the test specimen complies with the essential requirements in the standard.
FAILED The test was performed and the test specimen does not comply with the essential requirements in the standard.
REF The test is covered by a test in another report and/or on a similar test specimen.
NR The test is not relevant for the test specimen or has been waived by the manufacturer.

## 1.2 Test Specimen

| | |
| --- | --- |
| **Manufacturer** | Shape Robotics |
| **Name** | Dongle |
| **Model No.** | DNG002 |
| **Test Software** | Dongle_Firmware-6dbm_full_duty.hex |
| **Supply voltage** | 5 VDC by USB |

The Dongle contains electronics to control communication between a laptop and a Joint.
The Joint is an item containing two motor controlled joints, which enables the Joint to move.
The communication to Joint is via a 2.4 GHz radio link.
The communication between the Dongle and the laptop is via a USB cable, which also deliver power to the Dongle.
The Dongle also contains a Bluetooth radio, which is a pre certified module from RIGADO model BMD-100 with FCC ID: 2AA9B02 and IC: 12208A-02. This module is left out of the present test.

The 2.4 GHz radio used in both Joint and Dongle is the same module from ITEAD. The radio is based on a chipset from Nordic Semiconductor nRF24L01+.

The 2.4 GHz radio uses 6 pre-allocated frequencies in the range 2405 MHz to 2479 MHz.
The switching between the frequencies is done manually. (Pressing a button).
As the frequency range is greater than 10 MHz 3 frequencies are selected for test.

1. 2405 MHz
2. 2449 MHz
3. 2479 MHz

See photo 1 in appendix 1.

## 1.1 Auxiliary Equipment

### 1.1.1 Laptop

| | |
|---|---|
| **Manufacturer** | Lenovo |
| **Model** | X220 |
| **Product ID** | 42903WG |
| **Serial no.** | R9-KVYB6 11/12 |
| **Software** | Microsoft Windows 10 Professional |
| **Details** | - |
| **Supply voltage** | 20 VDC from AC/DC power supply |

### 1.1.2 AC/DC power supply for laptop

| | |
|---|---|
| **Manufacturer** | Lenovo |
| **Model** | 42T4424 |
| **Serial no.** | 11S42T4424Z1ZF3E15B6DA REV 05 |
| **Details** | - |
| **Supply voltage** | 100 – 240 VAC (120 VAC 60 Hz was used during tests) |
| **Output voltage** | 20 VDC |

### 1.1.3 AC/DC adaptor

| | |
|---|---|
| **Manufacturer** | Shape Robotics |
| **Model** | UBP-008 |
| **Details** | - |
| **Supply voltage** | 100 – 240 VAC (120 VAC 60 Hz was used during tests) |
| **Output voltage** | 5 VDC |

See photo 2 in appendix 1.

## 1.2 I/O ports / cables to test specimen

| I/O Port Cable | Type | Shielding | Cable length |
|---|---|---|---|
| USB | Std. | Shielded | 40 cm |

## 1.3 Test set-up

During test the test specimen was powered with 5 VDC via the USB cable, except during AC conducted emission were a laptop and a ACDC adaptor were used.

# 2 TESTS

## 2.1 Duty Cycle

| | |
|---|---|
| **Test specimen** | Dongle DNG002 |
| **Test specification** | 47 CFR Part 15 Subpart C |
| **Test method** | ANSI C63.10:2013 |
| **Comments** | None |
| **Temperature / Humidity** | 22°C / 35%RH |
| **Dates of measurements** | 2018-03-14 |
| **Test personnel** | Ruben Hansen |

### 2.1.1 Test setup

As it was not possibly to configure the 2.4 GHz radio module to 100 % duty cycle, a special test set up was made for the duty cycle measurement.

The worst case, during normal use, will be that the number of modules attached to the Dongle will go towards infinity. If that occurs the limiting factor will be the USB protocol since there is a 2 ms delay for each package.

For the test set up a Dongle was connected to a Laptop via USB cable and to a Joint via 2.4 GHz radio. At the laptop a special program was running. which was sending packages as fast as possible to the Joint via the Dongle and USB cable. The Joint was replying with full package. The package length was set to the maximal 32 Bytes.

The measurements were performed radiated with a small antenna placed next to the Dongle. There were a clear difference between the measured pulse level from the Dongle and the Joint.

See photo of test set up in appendix 1.

### 2.1.2 Test result

The duty cycle was measured at 2468.23 MHz.

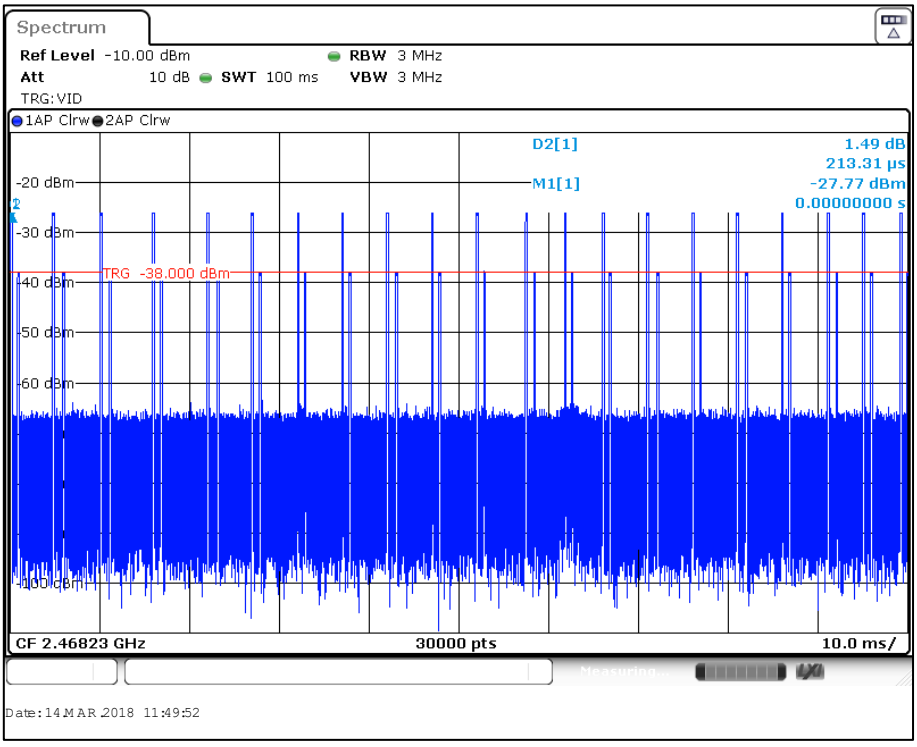


**Figure 1. Duty Cycle.**

The total pulse time was calculated in a spreadsheet based on the 30000 measurements points from the Analyzer.

| Total pulse time [ms] | Period time [ms] | Duty cycle [%] | Duty cycle correction factor [dB] |
|---|---|---|---|
| 4.67 | 100 | 4.69 | -26.58 |

**Table 1. Duty cycle.**

### 2.1.3 Test equipment

| Description | Supplier | Model | Tag no. | Cal. due date |
|---|---|---|---|---|
| Receiver EMI Test 10Hz-13.6GHz | Rohde & Schwarz | FSV 13 | 50092 | 2018-08-24 |

## 2.2 Field strength of fundamental

| | |
|---|---|
| **Test specimen** | Dongle DNG002 |
| **Test specification** | FCC 47 CFR Part 15.249 |
| **Test method** | ANSI C63.10:2013 |
| **Frequency range** | 2400-2483.5 MHz |
| **Limits** | FCC 47 CFR Part 15.249 (a) |
| **Comments** | None |
| **Temperature / Humidity** | 22°C / 37%RH |
| **Dates of measurements** | 2018-01-26 |
| **Test personnel** | Søren Søltoft |

### 2.2.1 Test setup

The test was performed with maximal possible transmission and with normal modulation. See sec 2.1.

The radiated maximum peak output power measurements were performed in the semi-anechoic chamber.
The fundamental was scanned with peak detector with the EUT in 3 octagonal positions and the turntable was varied between 0-360 degrees for maximum response.
The antenna distance during the measurements was 3.0 m.
The EUT height above the reference ground plane was 1.5 m

See appendix 1 for photo of test set up and test specimen orientation

### 2.2.2 Test limit

| Frequency range | Field strength limit | Field strength limit |
|---|---|---|
| 2400 – 2483.5 MHz | 50 mV/m | 94 dBµV/m |

**Table 2. Field strength of fundamental limit**.

### 2.2.3 Test results

| Fundamental: 2405 MHz | | | |
|---|---|---|---|
| **EUT axis** | **Vertical** | **Vertical -90 deg.** | **Horizontal** |
| **Antenna polarization** | Horizontal | Vertical | Horizontal |
| **Max. peak power** | 92.73 dBµV/m | 90.95 dBµV/m | 91.44 dBµV/m |
| **Result** | PASSED | PASSED | PASSED |

| Fundamental: 2449 MHz | | | |
|---|---|---|---|
| **EUT axis** | **Vertical** | **Vertical -90 deg.** | **Horizontal** |
| **Antenna polarization** | Horizontal | Vertical | Horizontal |
| **Max. peak power** | 92.39 dBµV/m | 90.81 dBµV/m | 92.18 dBµV/m |
| **Result** | PASSED | PASSED | PASSED |

| Fundamental: 2479 MHz | | | |
|---|---|---|---|
| **EUT axis** | **Vertical** | **Vertical -90 deg.** | **Horizontal** |
| **Antenna polarization** | Horizontal | Vertical | Horizontal |
| **Max. peak power** | 91.74 dBµV/m | 91.38 dBµV/m | 93.23 dBµV/m |
| **Result** | PASSED | PASSED | PASSED |

The nominal voltage of 5 VDC were variated between 85% and 115% without any changes in output power.

### 2.2.4 Test equipment

| Description | Supplier | Model | Tag no. | Cal. due date |
|---|---|---|---|---|
| Antenna Horn | Schwarzbeck | BBHA 9120 D | 20777 | 2019-02-18 |
| Analyzer 20Hz-26.5GHz | Rohde&Schwarz | ESI | 20763 | 2018-09-05 |

## 2.3 Radiated emission

| | |
|---|---|
| **Test specimen** | Dongle DNG002 |
| **Test specification** | 47 CFR Part 15.249 (d) (e) |
| **Test method** | ANSI C63.10:2013 |
| **Frequency range** | 30 MHz – 25 GHz |
| **Limits** | 47 CFR Part 15.249 (a) and 15.209 |
| **Comments** | None |
| **Temperature / Humidity** | 21°C / 37%RH and 21°C / 40%RH |
| **Dates of measurements** | 2018-01-19 and 2018-02-16 |
| **Test personnel** | Søren Søltoft |

### 2.3.1 Test setup

A measuring distance of 3 m was used during the tests.

The EUT was placed on a non-conductive table.

For measurements below 1 GHz. the height was 0.8 m and above 1 GHz the height was 1.5 m.

The test of radiated emission was performed in a semi anechoic chamber. The measurements were performed with both horizontal and vertical polarizations of the antenna. The antenna distance during the measurements was 3.0 m.

The measurement procedure is as follows:

1. A pre-measurement is performed with peak detector. The test object is measured in eight directions with the antenna in the frequency range 30-1000 MHz and in eighteen directions at frequencies above 1 GHz, with the antenna at three heights, 1.0 m, 1.5 m and 2.0 m. In the frequency range of 14 GHz to 25 GHz the measurement distance was 0.5 m.
2. If the emission is close or above the limit during the pre-measurement, the test object is scanned 360 degrees and the antenna height scanned from 1 to 4 m for maximum response. Then the emission is measured with the quasi-peak detector on frequencies below 1 GHz and with the CISPR-average detector above 1 GHz.

The following RBW were used:

30 MHz-1 GHz: RBW = 120 kHz

1-25 GHz: RBW = 1 MHz

See appendix 1 for photo of test set up

### 2.3.2 Test results

#### 2.3.2.1 Test result for Low channel 2405 MHz

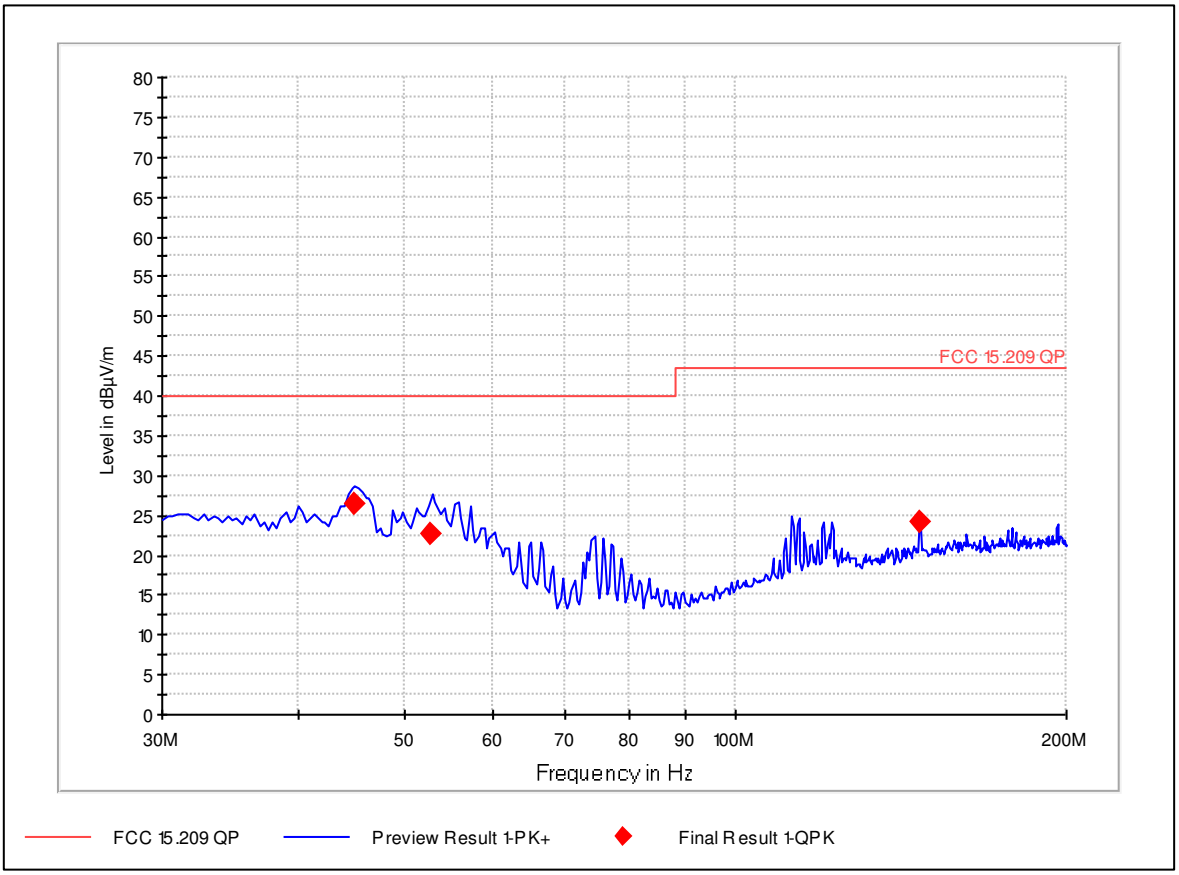


**Figure 2. Radiated emission test results. 30 - 200 MHz.**

| Frequency [MHz] | QP [dBuV/m] | BW [kHz] | Height [cm] | Pol. | Azimuth [deg] | Margin [dB] | Limit [dBuV/m] | Result |
|---|---|---|---|---|---|---|---|---|
| 44.909980 | 26.4 | 120.0 | 149.2 | V | 95.0 | 13.6 | 40.0 | PASSED |
| 52.775651 | 22.7 | 120.0 | 99.7 | V | 98.0 | 17.3 | 40.0 | PASSED |
| 146.914389 | 24.0 | 120.0 | 100.1 | V | 53.0 | 19.5 | 43.5 | PASSED |

**Table 3. Radiated emission test results. 30 - 200 MHz.**

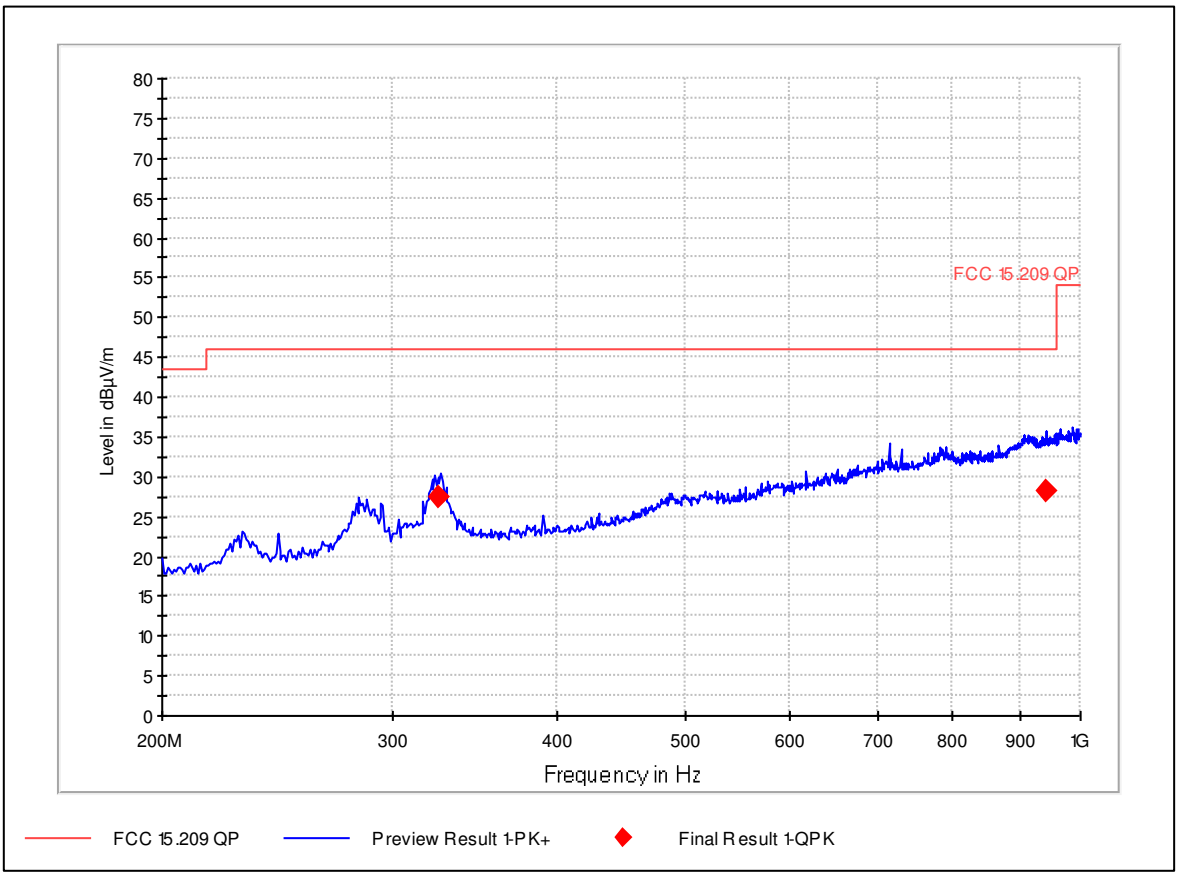


**Figure 3. Radiated emission test results. 200 - 1000 MHz.**

| Frequency [MHz] | QP [dBuV/m] | BW [kHz] | Height [cm] | Pol. | Azimuth [deg] | Margin [dB] | Limit [dBuV/m] | Result |
|---|---|---|---|---|---|---|---|---|
| 325.361703 | 27.4 | 120.0 | 99.7 | H | 273.0 | 18.6 | 46.0 | PASSED |
| 941.112966 | 28.3 | 120.0 | 225.0 | V | 188.0 | 17.7 | 46.0 | PASSED |

**Table 4. Radiated emission test results. 200 - 1000 MHz.**

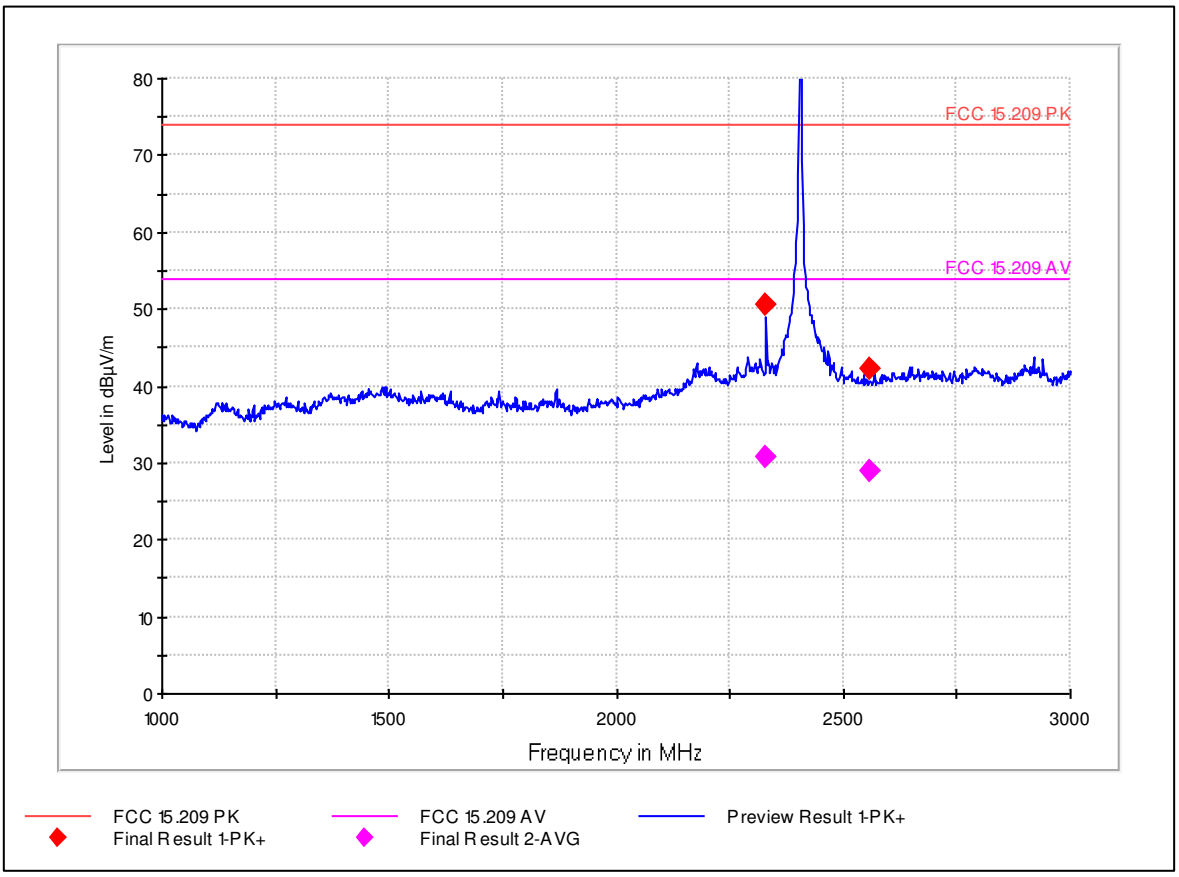


**Figure 4. Radiated emission test results 1 - 3 GHz.**

| Frequency [MHz] | Peak [dBuV/m] | BW [kHz] | Height [cm] | Pol. | Azimuth [deg] | Margin [dB] | Limit [dBuV/m] | Result |
|---|---|---|---|---|---|---|---|---|
| 2330.807823 | 50.7 | 1000 | 100.1 | H | 350.0 | 23.3 | 74.0 | PASSED |
| 2558.692777 | 42.3 | 1000 | 350.1 | V | 293.0 | 31.7 | 74.0 | PASSED |

**Table 5. Radiated emission test results 1 - 3 GHz. Peak detector.**

| Frequency [MHz] | Average [dBuV/m] | BW [kHz] | Height [cm] | Pol. | Azimuth [deg] | Margin [dB] | Limit [dBuV/m] | Result |
|---|---|---|---|---|---|---|---|---|
| 2330.807823 | 30.7 | 1000 | 100.1 | H | 350.0 | 23.3 | 54.00 | PASSED |
| 2558.692777 | 28.9 | 1000 | 350.1 | V | 293.0 | 25.1 | 54.00 | PASSED |

**Table 6. Radiated emission test results- 1 - 3 GHz. Average detector.**

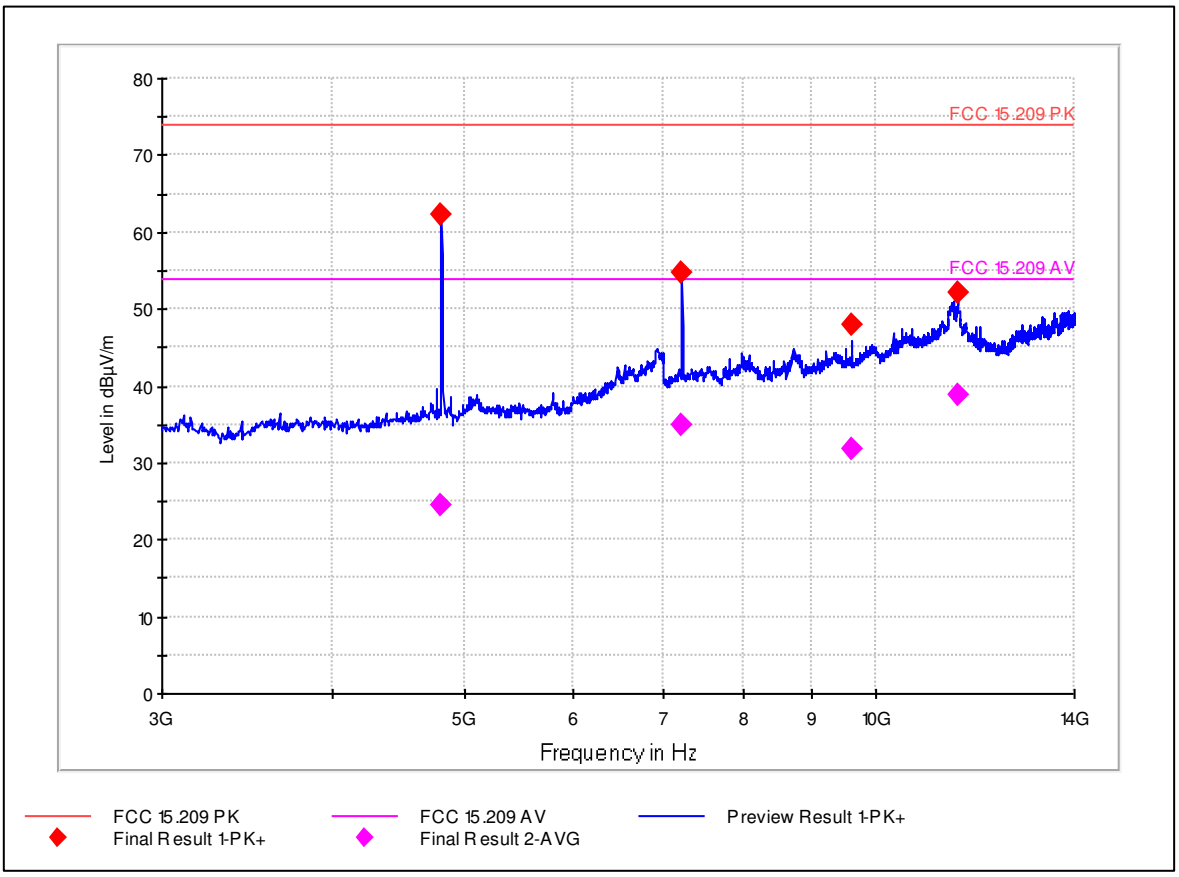


**Figure 5. Radiated emission test results 3 - 14 GHz.**

| Frequency [MHz] | Peak [dBuV/m] | BW [kHz] | Height [cm] | Pol. | Azimuth [deg] | Margin [dB] | Limit [dBuV/m] | Result |
|---|---|---|---|---|---|---|---|---|
| 4805.774234 | 62.2 | 1000 | 100.1 | H | 103.0 | 11.8 | 74.0 | PASSED |
| 7215.359854 | 54.8 | 1000 | 199.9 | H | 21.0 | 19.2 | 74.0 | PASSED |
| 9619.930493 | 47.8 | 1000 | 231.2 | V | 319.0 | 26.2 | 74.0 | PASSED |
| 11501.410486 | 52.1 | 1000 | 329.0 | V | 6.0 | 21.9 | 74.0 | PASSED |

**Table 7. Radiated emission test results. 3 - 14 GHz. Peak detector.**

The following frequencies are harmonic of the fundamental and thus pulsed.

The average value is calculated by correcting the Peak detector level with the Duty Cycle Correction Factor found in section 2.1.

| Frequency [MHz] | Peak [dBuV/m] | Correction Factor [dB] | Average [dBuV/m] | Margin [dB] | Limit [dBuV/m] | Result |
|---|---|---|---|---|---|---|
| 4805.774234 | 62.2 | -26.58 | 35.62 | 18.38 | 54.0 | PASSED |
| 7215.359854 | 54.8 | -26.58 | 28.22 | 25.78 | 54.0 | PASSED |
| 9619.930493 | 47.8 | -26.58 | 21.22 | 32.78 | 54.0 | PASSED |

**Table 8. Radiated emission test results 3 - 14 GHz. Average. Pulsed signal.**

| Frequency [MHz] | Average [dBuV/m] | BW [kHz] | Height [cm] | Pol. | Azimuth [deg] | Margin [dB] | Limit [dBuV/m] | Result |
|---|---|---|---|---|---|---|---|---|
| 11501.410486 | 39.0 | 1000. | 329.0 | V | 6.0 | 15.0 | 54.0 | PASSED |

**Table 9. Radiated emission test results 3 - 14 GHz. Average. Non pulsed signal.**

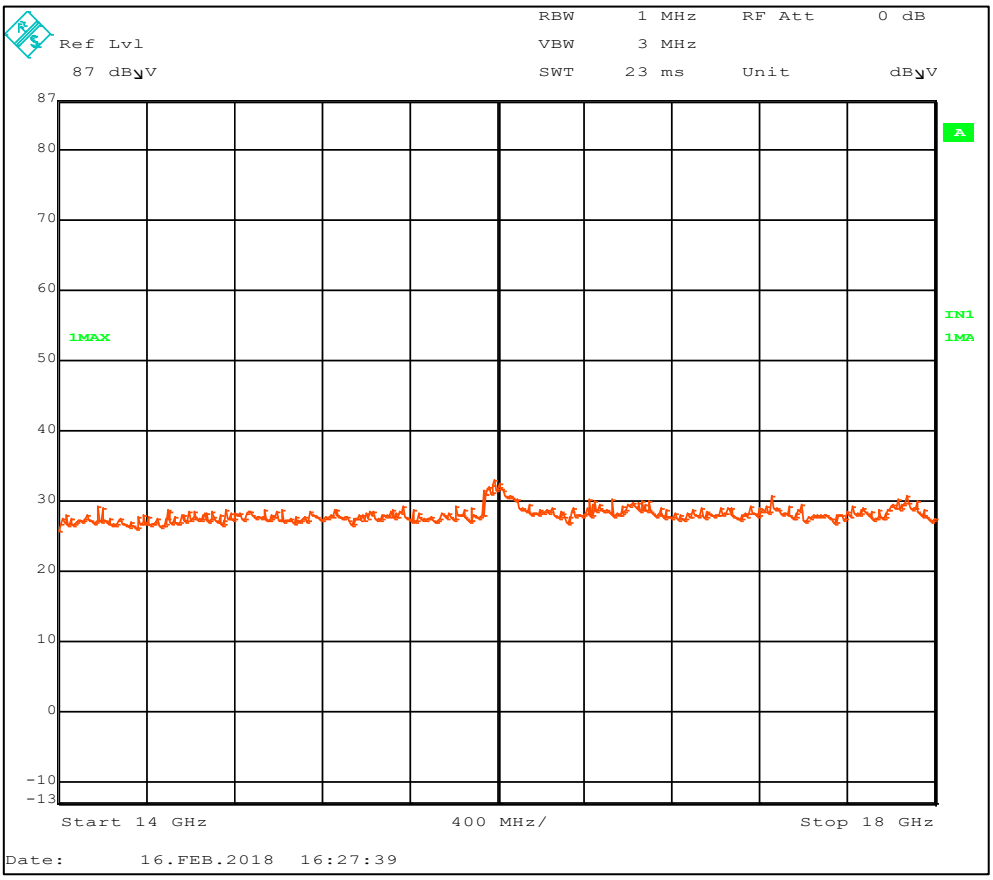


**Figure 6 Radiated emission test results 14 - 18 GHz. Peak detector.**

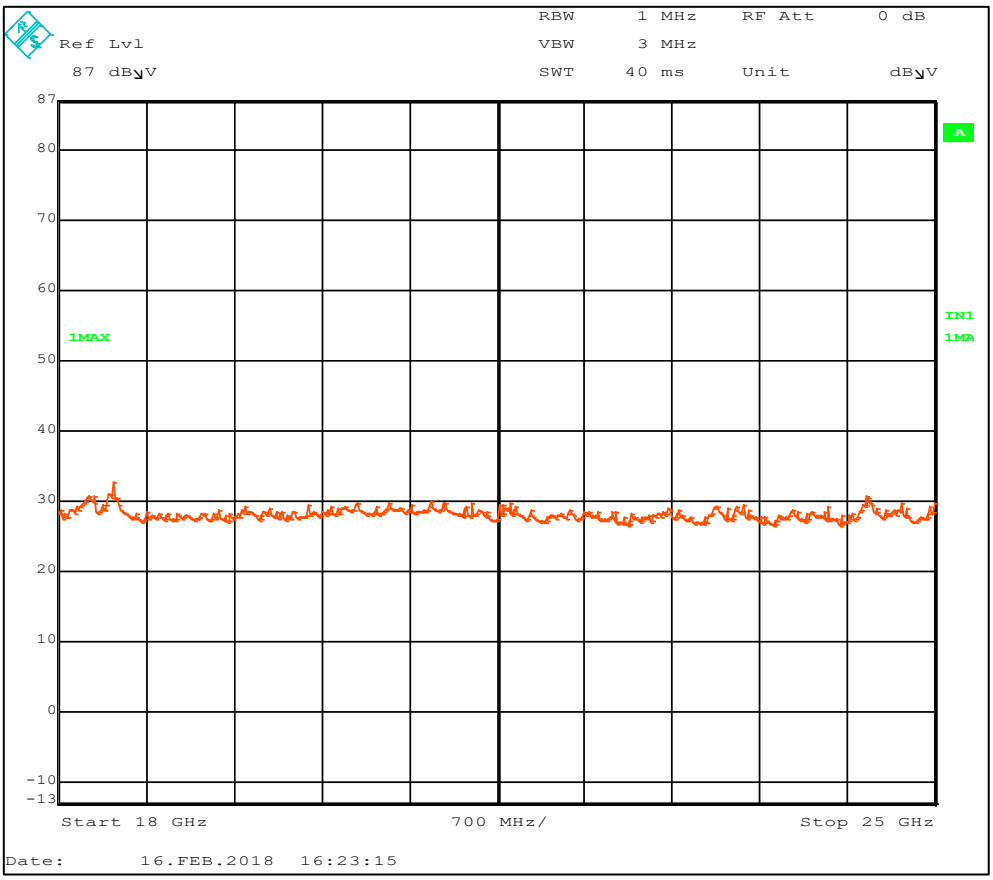


**Figure 7. Radiated emission test results 18 - 25 GHz. Peak detector**

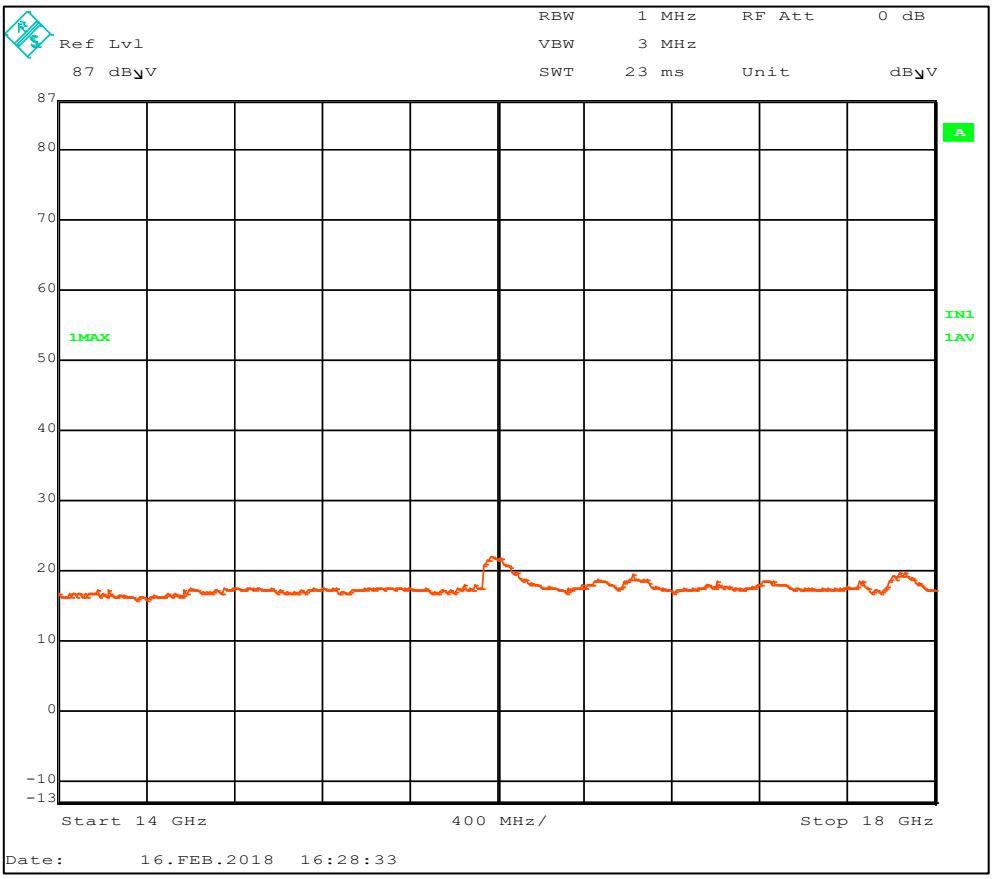


**Figure 8. Radiated emission test results 14 - 18 GHz. Average detector.**

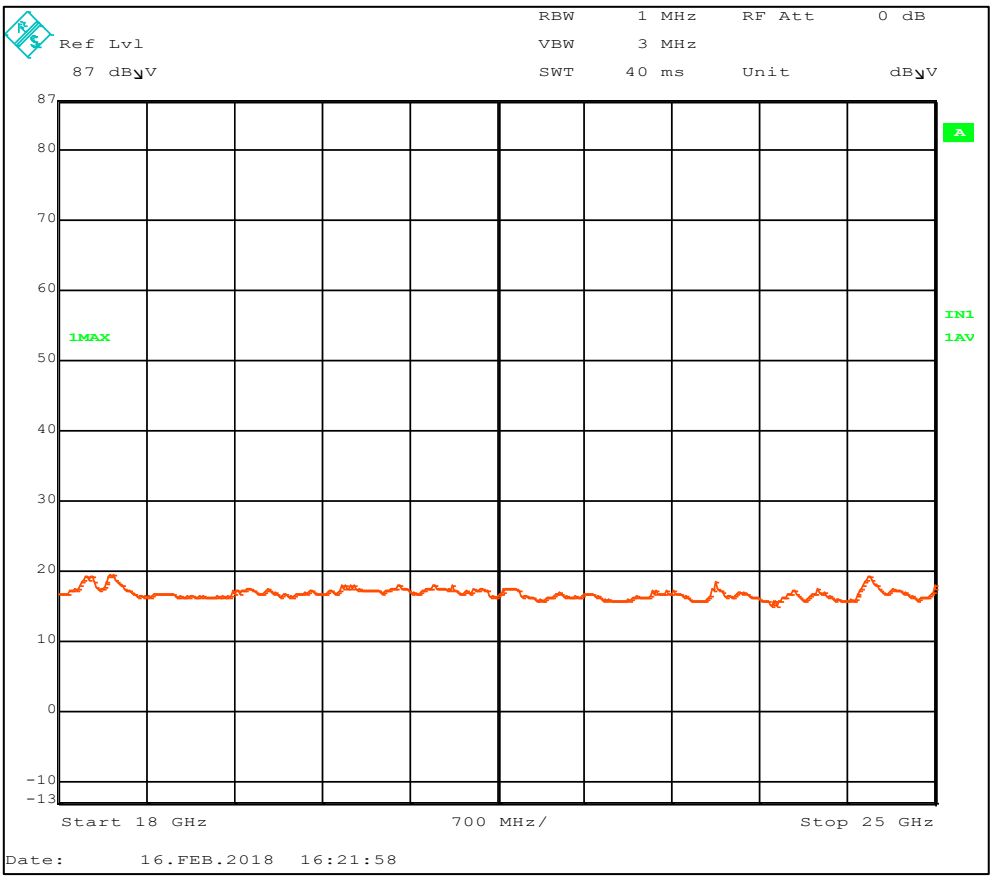


**Figure 9. Radiated emission test results 18 - 25 GHz. Average detector.**

| Average Limit 3 m. | Peak limit 3 m | 3 m / 0.5 m factor | Average Limit 0.5 m. | Peak limit 0.5 m |
|---|---|---|---|---|
| dBµV/m | dBµV/m | dB | dBµV/m | dBµV/m |
| 53.98 | 73.98 | 15.56 dB | 69.54 | 89.54 |

**Table 10. Calculation of limit at 0.5 m.**

| Frequency | AF | Cable loss | Correction factor |
|---|---|---|---|
| GHz | dB/m | dB | dB/m |
| 14 | 37,1 | < 2 | 39.1 |
| 18 | 37,4 | < 2 | 39.4 |
| 18 | 40.3 | < 2 | 42.3 |
| 25 | 40.6 | < 2 | 42.6 |

**Table 11. Correction factors 14 – 25 GHz.**

| Frequency [MHz] | Peak [dBuV/m] | BW [kHz] | Height [cm] | Pol. | Azimuth [deg] | Margin [dB] | Limit [dBuV/m] | Result |
|---|---|---|---|---|---|---|---|---|
| - | - | - | - | - | - | - | 89.54 | PASSED |

**Table 12. Radiated emission test results. 14 - 25 GHz. Peak detector.**

| Frequency [MHz] | Average [dBuV/m] | BW [kHz] | Height [cm] | Pol. | Azimuth [deg] | Margin [dB] | Limit [dBuV/m] | Result |
|---|---|---|---|---|---|---|---|---|
| - | - | - | - | - | - | - | 69.54 | PASSED |

**Table 13. Radiated emission test results 14 – 25 GHz. Average detector.**

#### 2.3.2.2 Test result for Middle channel 2449 MHz

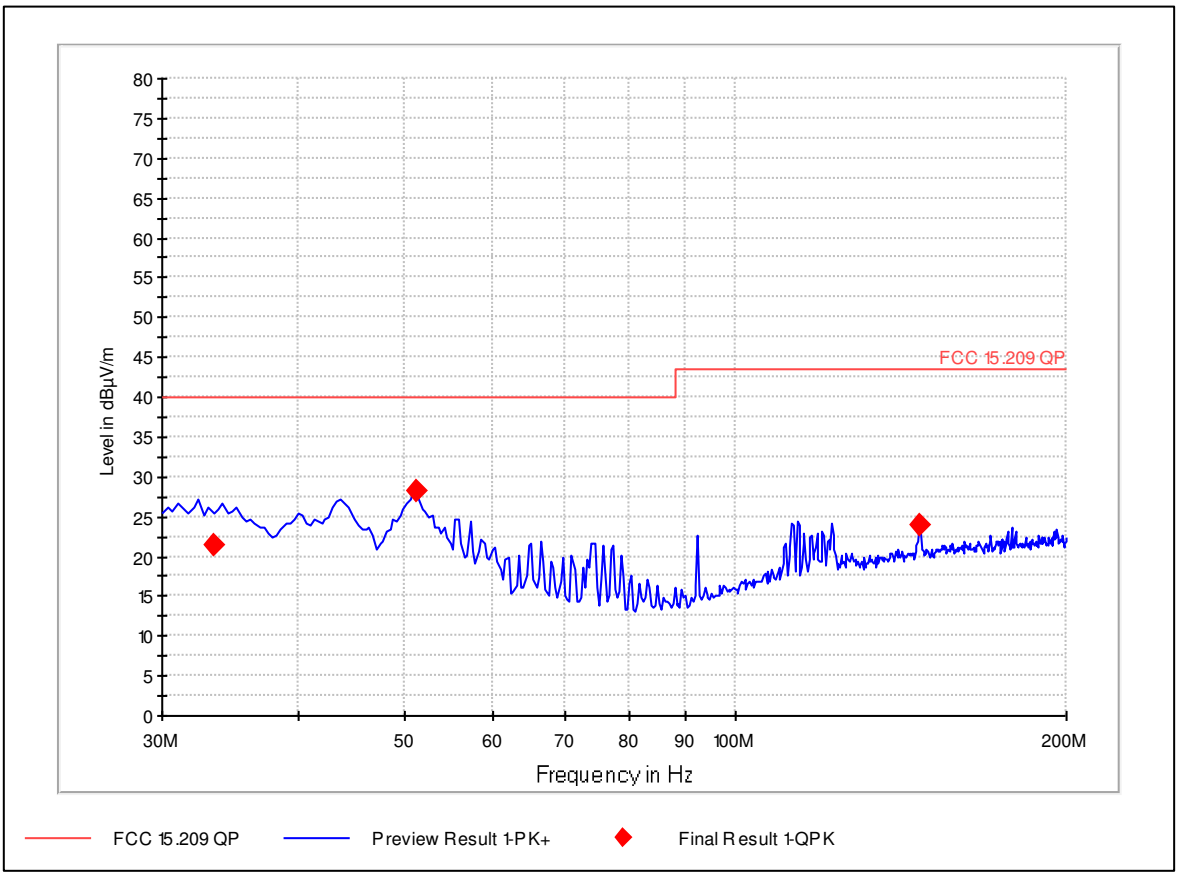


**Figure 10. Radiated emission test results. 30 - 200 MHz.**

| Frequency [MHz] | QP [dBuV/m] | BW [kHz] | Height [cm] | Pol. | Azimuth [deg] | Margin [dB] | Limit [dBuV/m] | Result |
|---|---|---|---|---|---|---|---|---|
| 33.454770 | 21.3 | 120.0 | 297.1 | V | 90.0 | 18.7 | 40.0 | PASSED |
| 51.261563 | 28.1 | 120.0 | 319.0 | V | 172.0 | 11.9 | 40.0 | PASSED |
| 146.823707 | 23.9 | 120.0 | 99.7 | V | 46.0 | 19.6 | 43.5 | PASSED |

**Table 14. Radiated emission test results. 30 - 200 MHz.**

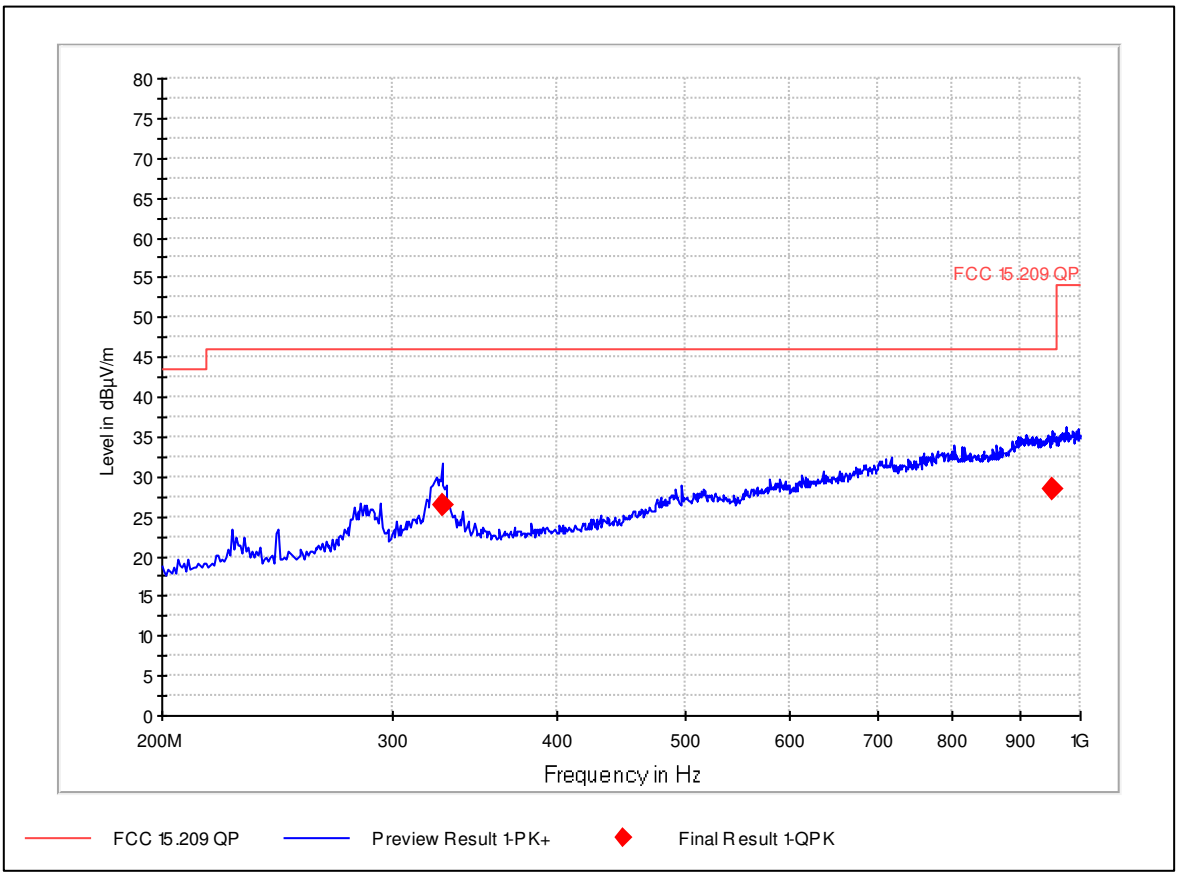


**Figure 11. Radiated emission test results. 200 - 1000 MHz.**

| Frequency [MHz] | QP [dBuV/m] | BW [kHz] | Height [cm] | Pol. | Azimuth [deg] | Margin [dB] | Limit [dBuV/m] | Result |
|---|---|---|---|---|---|---|---|---|
| 326.593307 | 26.5 | 120.0 | 99.7 | H | 288.0 | 19.5 | 46.0 | PASSED |
| 952.435411 | 28.5 | 120.0 | 154.0 | H | 291.0 | 17.5 | 46.0 | PASSED |

**Table 15. Radiated emission test results. 200 - 1000 MHz.**

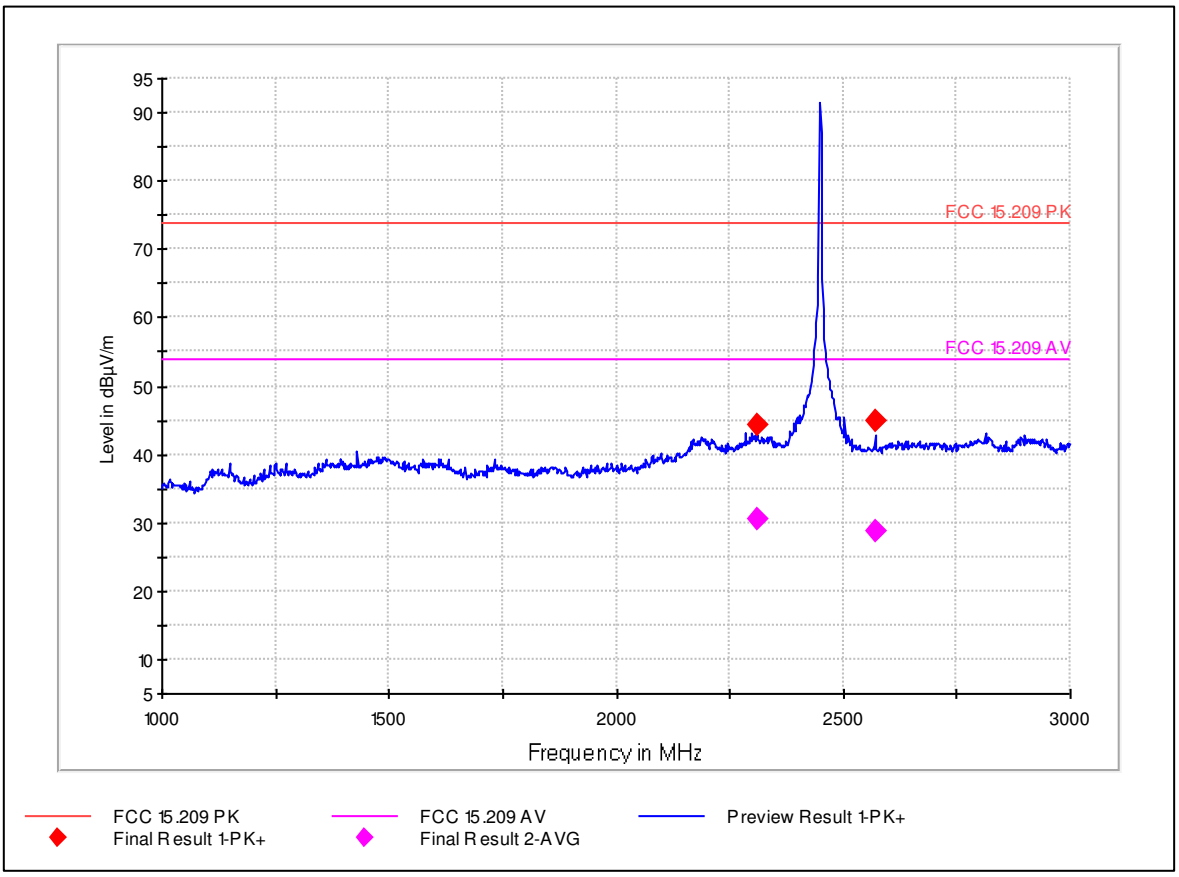


**Figure 12. Radiated emission test results 1 - 3 GHz.**

| Frequency [MHz] | Peak [dBuV/m] | BW [kHz] | Height [cm] | Pol. | Azimuth [deg] | Margin [dB] | Limit [dBuV/m] | Result |
|---|---|---|---|---|---|---|---|---|
| 2312.980227 | 44.2 | 1000 | 172.1 | H | 0.0 | 29.8 | 74.0 | PASSED |
| 2570.586785 | 45.0 | 1000 | 199.9 | H | 203.0 | 29.0 | 74.0 | PASSED |

**Table 16. Radiated emission test results 1 - 3 GHz. Peak detector.**

| Frequency [MHz] | Average [dBuV/m] | BW [kHz] | Height [cm] | Pol. | Azimuth [deg] | Margin [dB] | Limit [dBuV/m] | Result |
|---|---|---|---|---|---|---|---|---|
| 2312.980227 | 30.5 | 1000 | 172.1 | H | 0.0 | 23.5 | 54.0 | PASSED |
| 2570.586785 | 28.9 | 1000 | 199.9 | H | 203.0 | 25.1 | 54.0 | PASSED |

**Table 17. Radiated emission test results- 1 - 3 GHz. Average detector.**

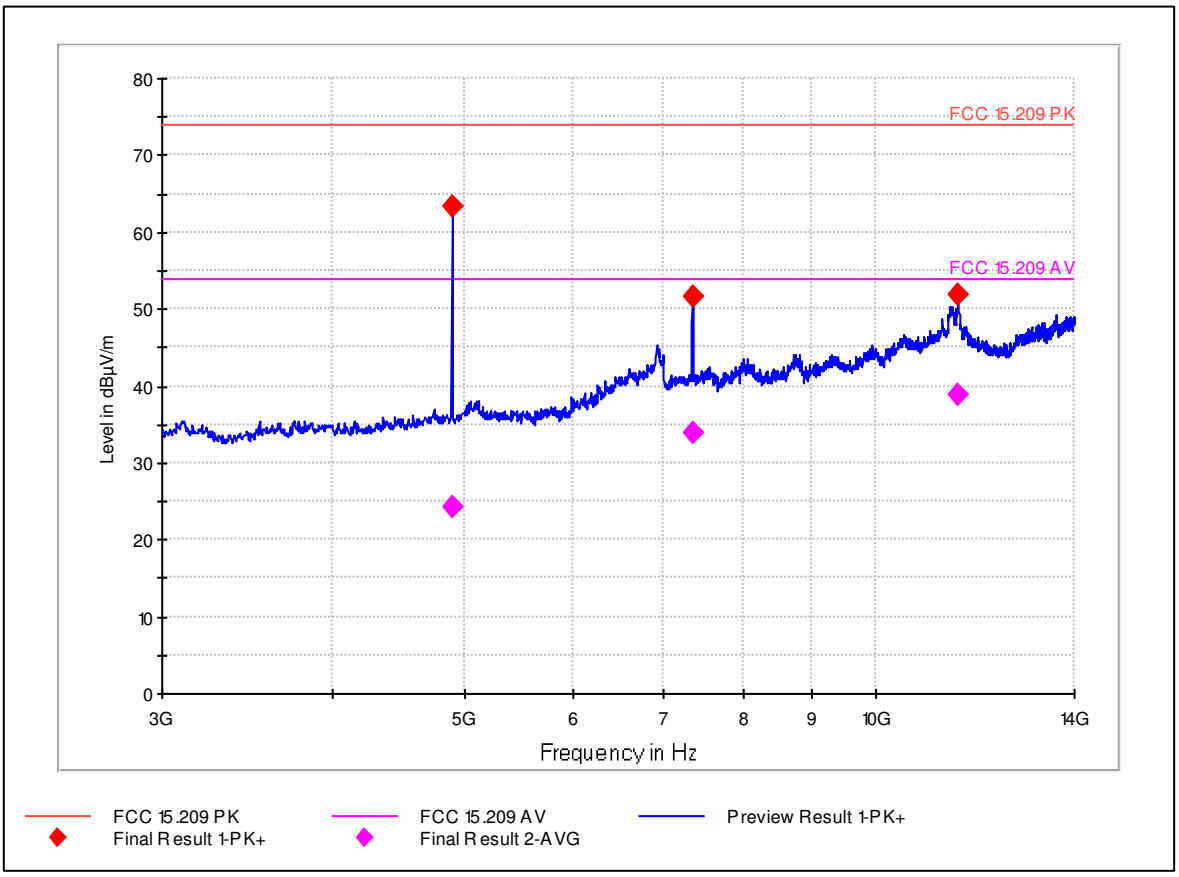


**Figure 13. Radiated emission test results 3 - 14 GHz.**

| Frequency [MHz] | Peak [dBuV/m] | BW [kHz] | Height [cm] | Pol. | Azimuth [deg] | Margin [dB] | Limit [dBuV/m] | Result |
|---|---|---|---|---|---|---|---|---|
| 4894.918575 | 63.3 | 1000 | 150.2 | H | 95.0 | 10.7 | 74.0 | PASSED |
| 7346.753895 | 51.6 | 1000 | 99.9 | V | 320.0 | 22.4 | 74.0 | PASSED |
| 11502.210486 | 51.9 | 1000 | 395.2 | H | 163.0 | 22.1 | 74.0 | PASSED |

**Table 18. Radiated emission test results. 3 - 14 GHz. Peak detector.**

The following frequencies are harmonic of the fundamental and thus pulsed.
The average value is calculated by correcting the Peak detector level with the Duty Cycle Correction Factor found in section 2.1.

| Frequency [MHz] | Peak [dBuV/m] | Correction Factor [dB] | Average [dBuV/m] | Margin [dB] | Limit [dBuV/m] | Result |
|---|---|---|---|---|---|---|
| 4894.918575 | 63.3 | -26.58 | 36.72 | 17.28 | 54.0 | PASSED |
| 7346.753895 | 51.6 | -26.58 | 25.02 | 28.98 | 54.0 | PASSED |

**Table 19. Radiated emission test results 3 - 14 GHz. Average. Pulsed signal.**

| Frequency [MHz] | Average [dBuV/m] | BW [kHz] | Height [cm] | Pol. | Azimuth [deg] | Margin [dB] | Limit [dBuV/m] | Result |
|---|---|---|---|---|---|---|---|---|
| 11502.210486 | 38.8 | 1000 | 395.2 | H | 163.0 | 15.2 | 54.0 | PASSED |

**Table 20. Radiated emission test results 3 - 14 GHz. Average. Non pulsed signal**

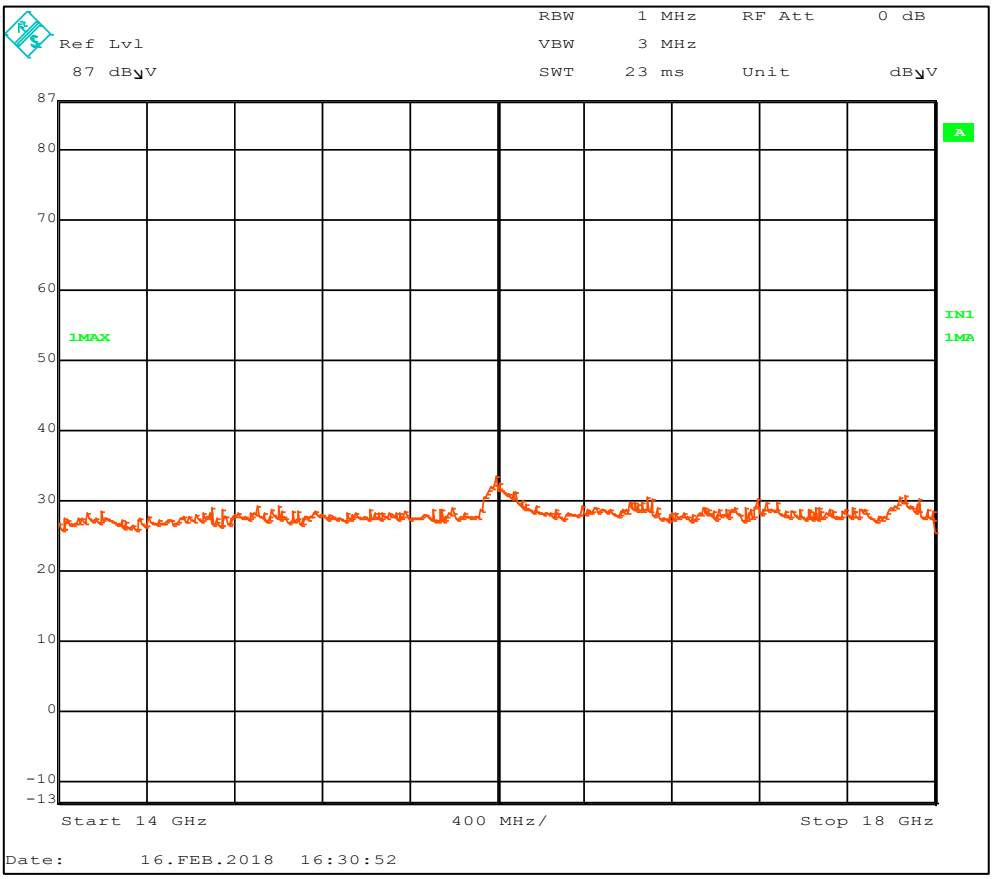


**Figure 14. Radiated emission test results 14 - 18 GHz. Peak detector.**

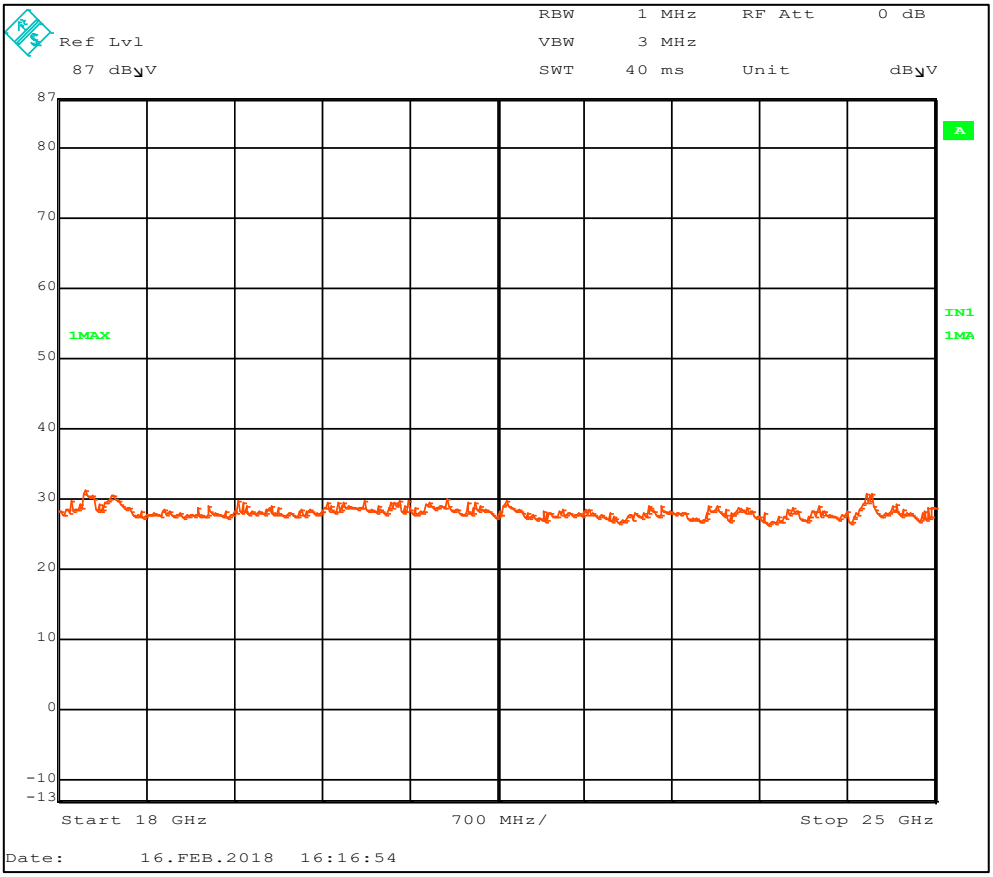


**Figure 15. Radiated emission test results 18 - 25 GHz. Peak detector.**

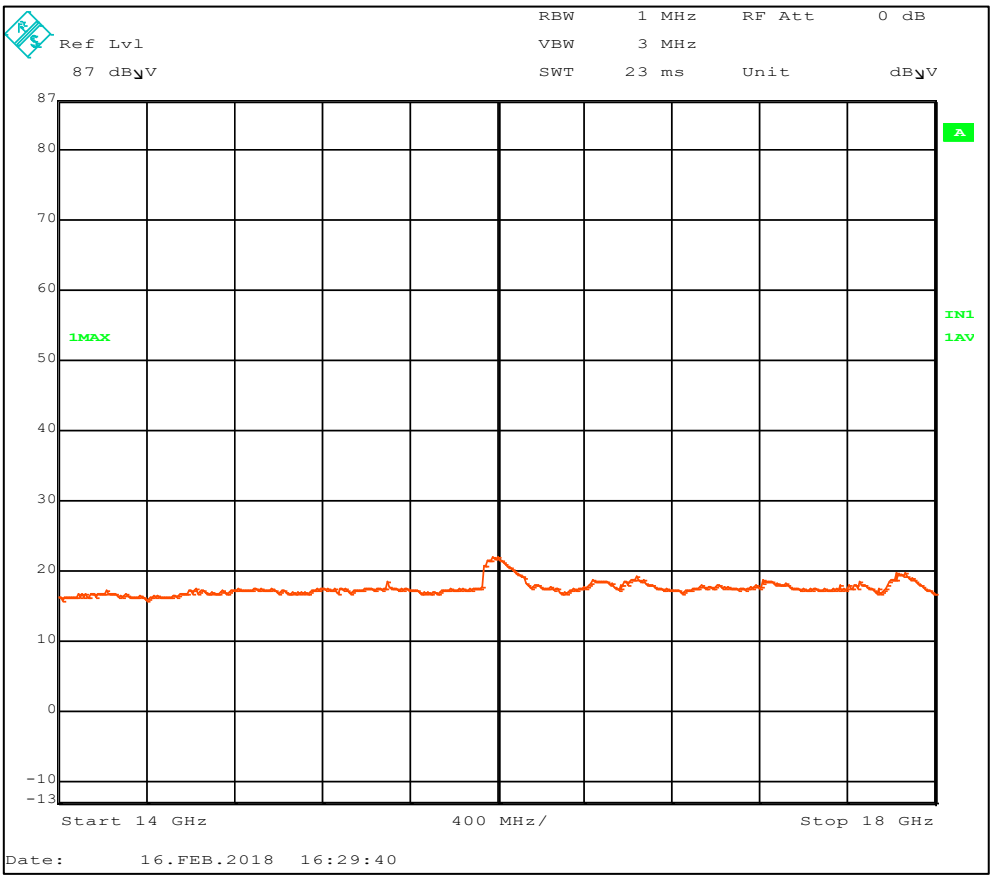


**Figure 16. Radiated emission test results 18 - 25 GHz. Average detector.**

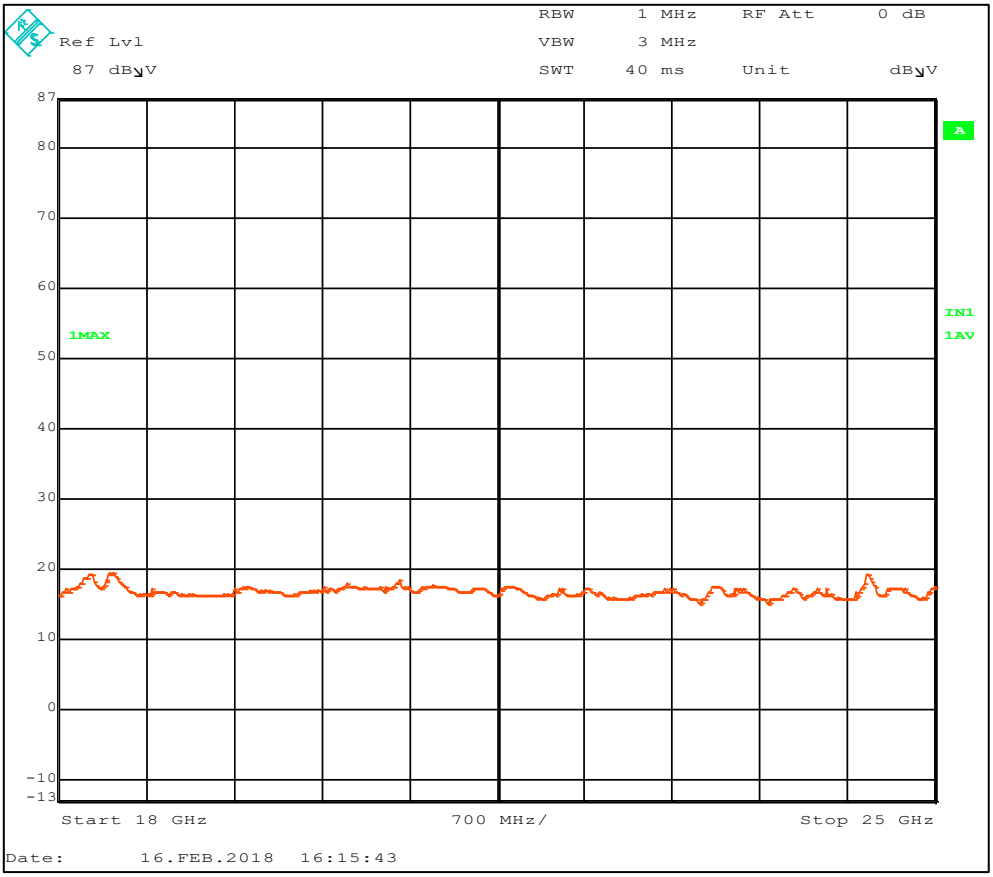


**Figure 17. Radiated emission test results 18 - 25 GHz. Average detector.**

| Average Limit 3 m. | Peak limit 3 m | 3 m / 0.5 m factor | Average Limit 0.5 m. | Peak limit 0.5 m |
|---|---|---|---|---|
| dBµV/m | dBµV/m | dB | dBµV/m | dBµV/m |
| 53.98 | 73.98 | 15.56 dB | 69.54 | 89.54 |

**Table 21. Calculation of limit at 0.5 m.**

| Frequency | AF | Cable loss | Correction factor |
|---|---|---|---|
| GHz | dB/m | dB | dB/m |
| 14 | 37,1 | < 2 | 39.1 |
| 18 | 37,4 | < 2 | 39.4 |
| 18 | 40.3 | < 2 | 42.3 |
| 25 | 40.6 | < 2 | 42.6 |

**Table 22. Correction factors 14 – 25 GHz.**

| Frequency [MHz] | Peak [dBuV/m] | BW [kHz] | Height [cm] | Pol. | Azimuth [deg] | Margin [dB] | Limit [dBuV/m] | Result |
|---|---|---|---|---|---|---|---|---|
| - | - | - | - | - | - | - | 89.54 | PASSED |

**Table 23. Radiated emission test results. 14 - 25 GHz. Peak detector.**

| Frequency [MHz] | Average [dBuV/m] | BW [kHz] | Height [cm] | Pol. | Azimuth [deg] | Margin [dB] | Limit [dBuV/m] | Result |
|---|---|---|---|---|---|---|---|---|
| - | - | - | - | - | - | - | 69.54 | PASSED |

**Table 24. Radiated emission test results 3 - 14 GHz. Average detector.**

#### 2.3.2.3 Test result for High channel 2479 MHz.

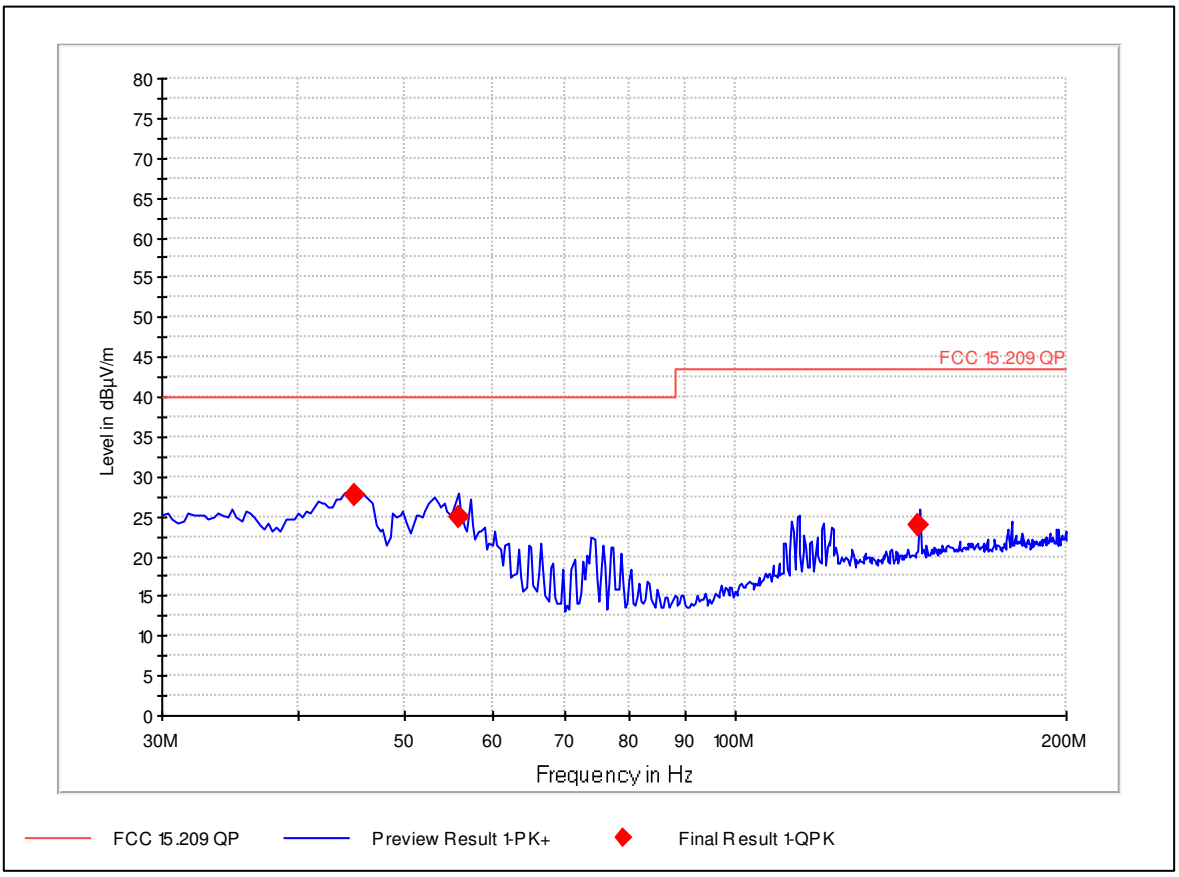


**Figure 18. Radiated emission test results. 30 - 200 MHz.**

| Frequency [MHz] | QP [dBuV/m] | BW [kHz] | Height [cm] | Pol. | Azimuth [deg] | Margin [dB] | Limit [dBuV/m] | Result |
|---|---|---|---|---|---|---|---|---|
| 45.009980 | 27.7 | 120.0 | 162.7 | V | 4.0 | 12.3 | 40.0 | PASSED |
| 55.801784 | 25.0 | 120.0 | 100.0 | V | 307.0 | 15.0 | 40.0 | PASSED |
| 146.774389 | 23.9 | 120.0 | 100.1 | V | 45.0 | 19.6 | 43.5 | PASSED |

**Table 25. Radiated emission test results. 30 - 200 MHz.**

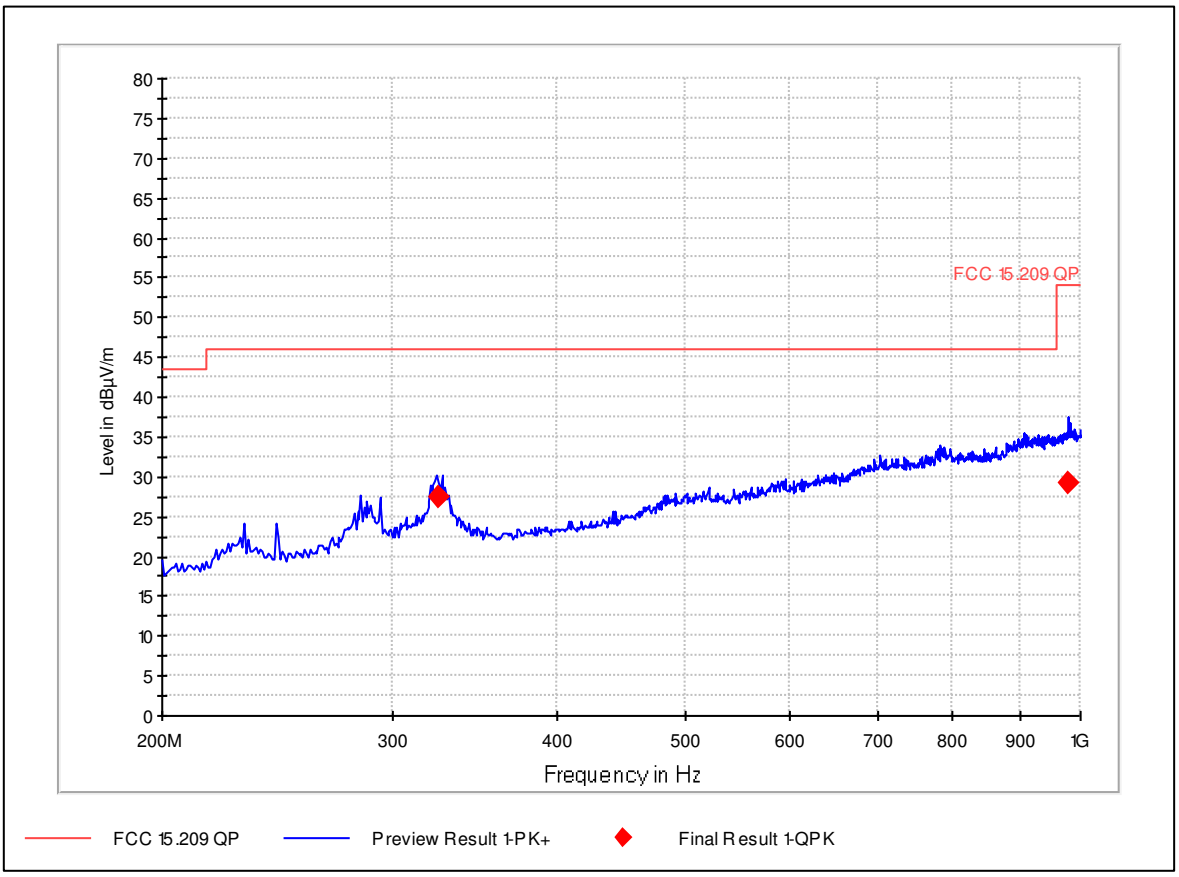


**Figure 19. Radiated emission test results. 200 - 1000 MHz.**

| Frequency [MHz] | QP [dBuV/m] | BW [kHz] | Height [cm] | Pol. | Azimuth [deg] | Margin [dB] | Limit [dBuV/m] | Result |
|---|---|---|---|---|---|---|---|---|
| 324.576894 | 27.5 | 120.0 | 130.1 | H | 273.0 | 18.5 | 46.0 | PASSED |
| 979.489920 | 29.1 | 120.0 | 100.1 | H | 190.0 | 24.9 | 54.0 | PASSED |

**Table 26. Radiated emission test results. 200 - 1000 MHz.**

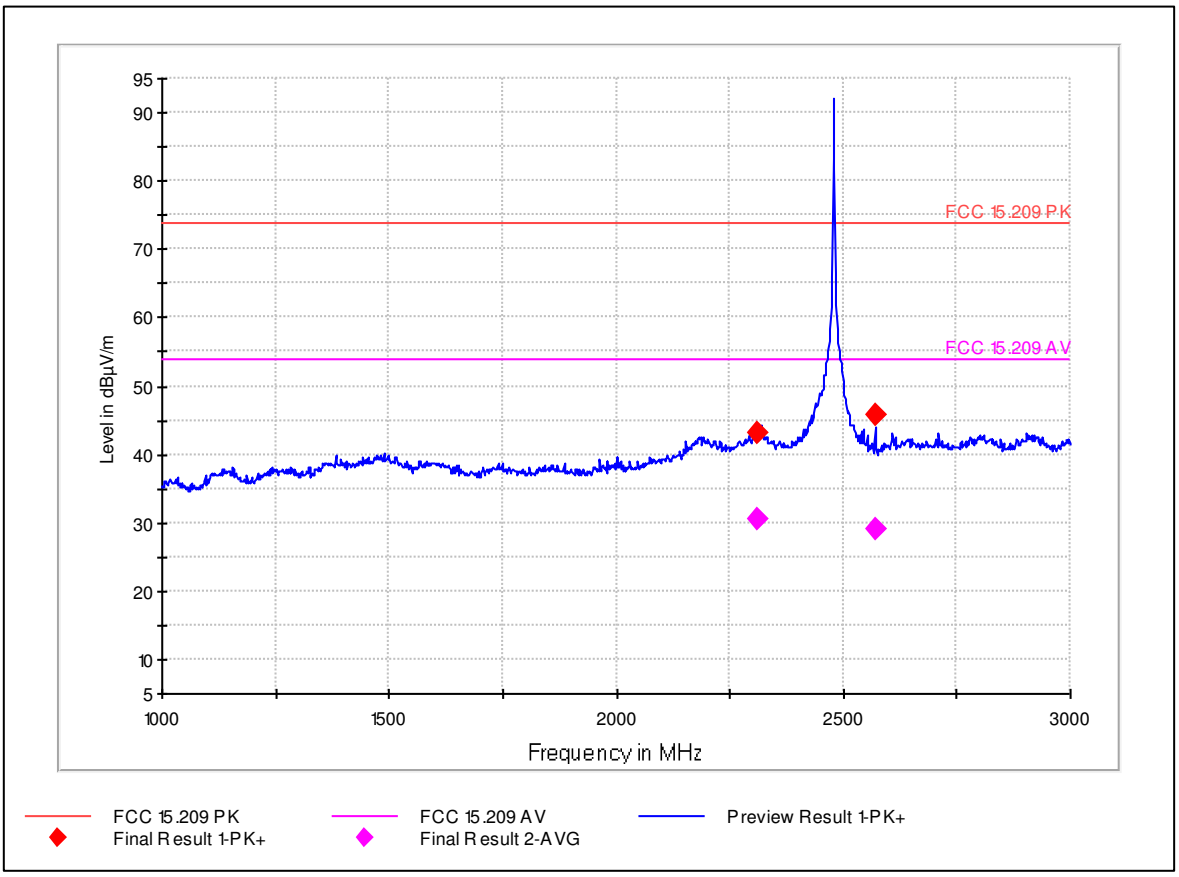


**Figure 20. Radiated emission test results 1 - 3 GHz.**

| Frequency [MHz] | Peak [dBuV/m] | BW [kHz] | Height [cm] | Pol. | Azimuth [deg] | Margin [dB] | Limit [dBuV/m] | Result |
|---|---|---|---|---|---|---|---|---|
| 2309.844275 | 43.3 | 1000 | 172.0 | H | 91.0 | 30.7 | 74.0 | PASSED |
| 2570.386785 | 45.9 | 1000 | 199.9 | H | 218.0 | 28.1 | 74.0 | PASSED |

**Table 27. Radiated emission test results 1 - 3 GHz. Peak detector.**

| Frequency [MHz] | Average [dBuV/m] | BW [kHz] | Height [cm] | Pol. | Azimuth [deg] | Margin [dB] | Limit [dBuV/m] | Result |
|---|---|---|---|---|---|---|---|---|
| 2309.844275 | 30.6 | 1000 | 172.0 | H | 91.0 | 23.4 | 54.0 | PASSED |
| 2570.386785 | 29.1 | 1000 | 199.9 | H | 218.0 | 24.9 | 54.0 | PASSED |

**Table 28. Radiated emission test results- 1 - 3 GHz. Average detector.**

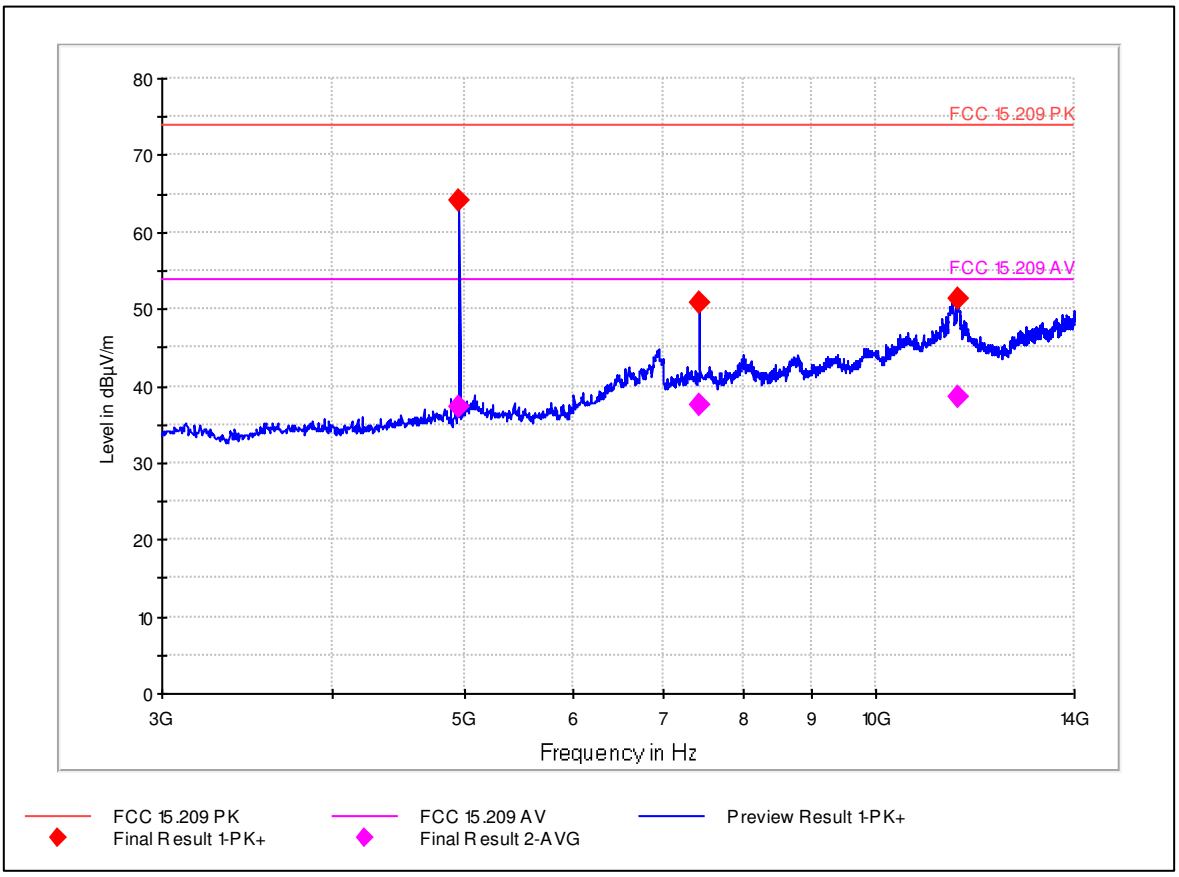


**Figure 21. Radiated emission test results 3 - 14 GHz.**

| Frequency [MHz] | Peak [dBuV/m] | BW [kHz] | Height [cm] | Pol. | Azimuth [deg] | Margin [dB] | Limit [dBuV/m] | Result |
|---|---|---|---|---|---|---|---|---|
| 4956.523336 | 64.2 | 1000 | 150.1 | H | 101.0 | 9.8 | 74.0 | PASSED |
| 7436.883256 | 50.7 | 1000 | 99.9 | V | 119.0 | 23.3 | 74.0 | PASSED |
| 11502.697004 | 51.2 | 1000 | 299.0 | H | 238.0 | 22.8 | 74.0 | PASSED |

**Table 29. Radiated emission test results. 3 - 14 GHz. Peak detector.**

The following frequencies are harmonic of the fundamental and thus pulsed.
The average value is calculated by correcting the Peak detector level with the Duty Cycle Correction Factor found in section 2.1.

| Frequency [MHz] | Peak [dBuV/m] | Correction Factor [dB] | Average [dBuV/m] | Margin [dB] | Limit [dBuV/m] | Result |
|---|---|---|---|---|---|---|
| 4956.523336 | 64.2 | -26.58 | 37.62 | 16.38 | 54.0 | PASSED |
| 7436.883256 | 50.7 | -26.58 | 24.12 | 29.88 | 54.0 | PASSED |

**Table 30. Radiated emission test results 3 - 14 GHz. Average. Pulsed signal.**

| Frequency [MHz] | Average [dBuV/m] | BW [kHz] | Height [cm] | Pol. | Azimuth [deg] | Margin [dB] | Limit [dBuV/m] | Result |
|---|---|---|---|---|---|---|---|---|
| 11502.697004 | 38.5 | 1000 | 299.0 | H | 238.0 | 15.5 | 54.0 | PASSED |

**Table 31. Radiated emission test results 3 - 14 GHz. Average. Non pulse signal**

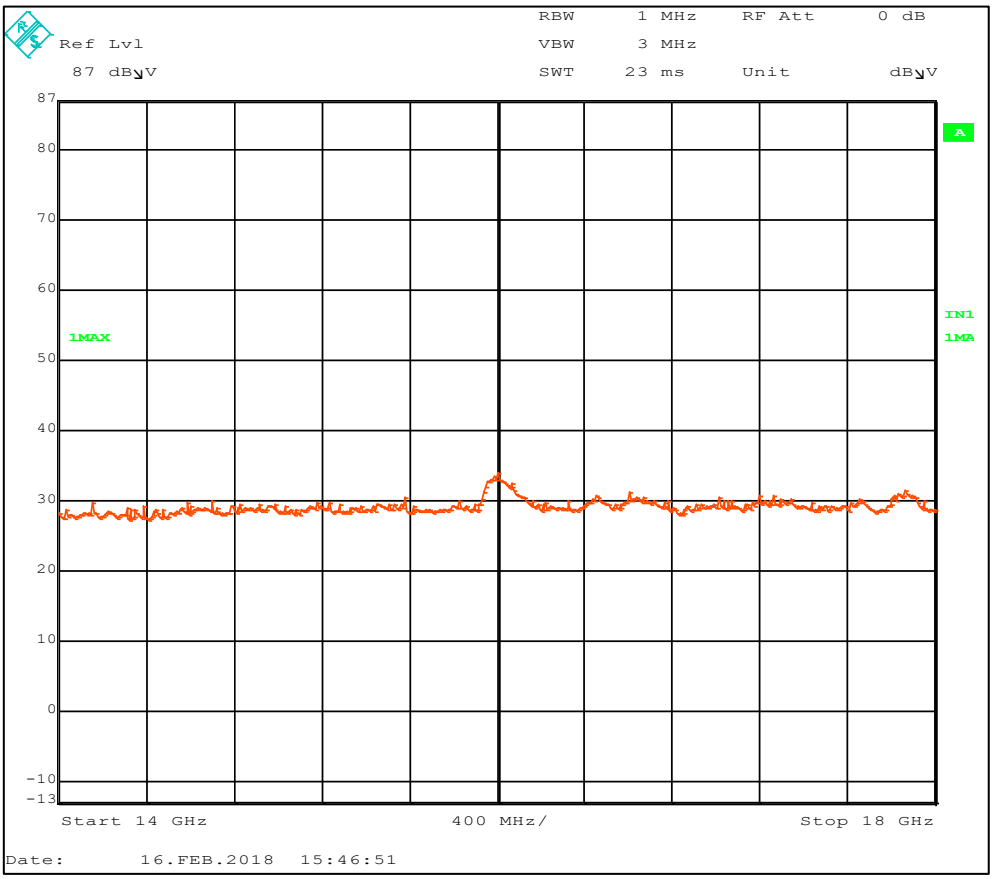


**Figure 22. Radiated emission test results 14 - 18 GHz. Peak detector.**

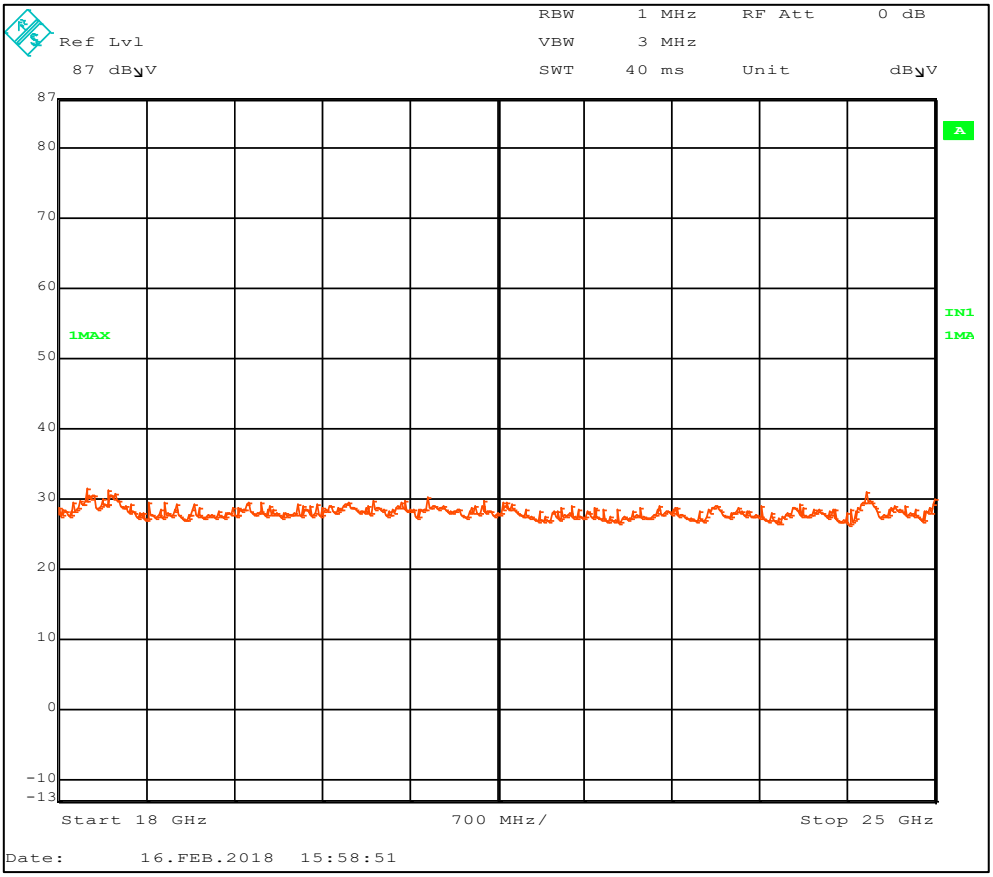


**Figure 23. Radiated emission test results 18 - 25 GHz. Peak detector.**

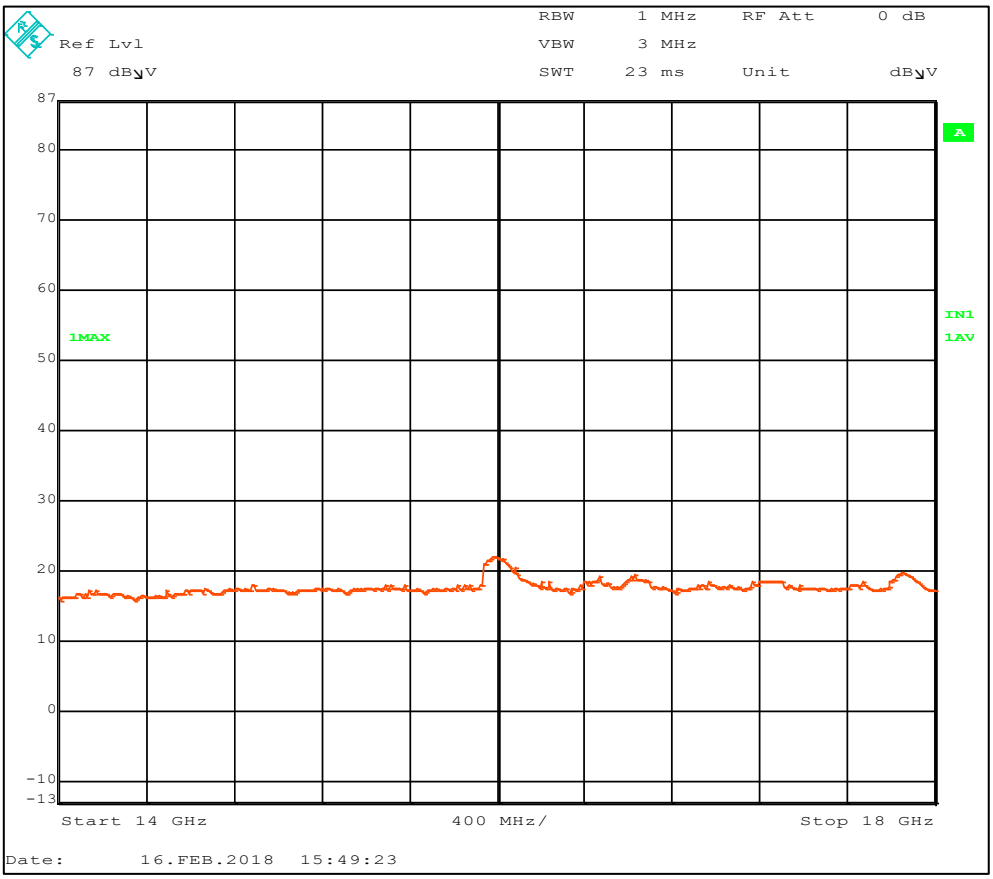


**Figure 24. Radiated emission test results 14 - 18 GHz. Average detector.**

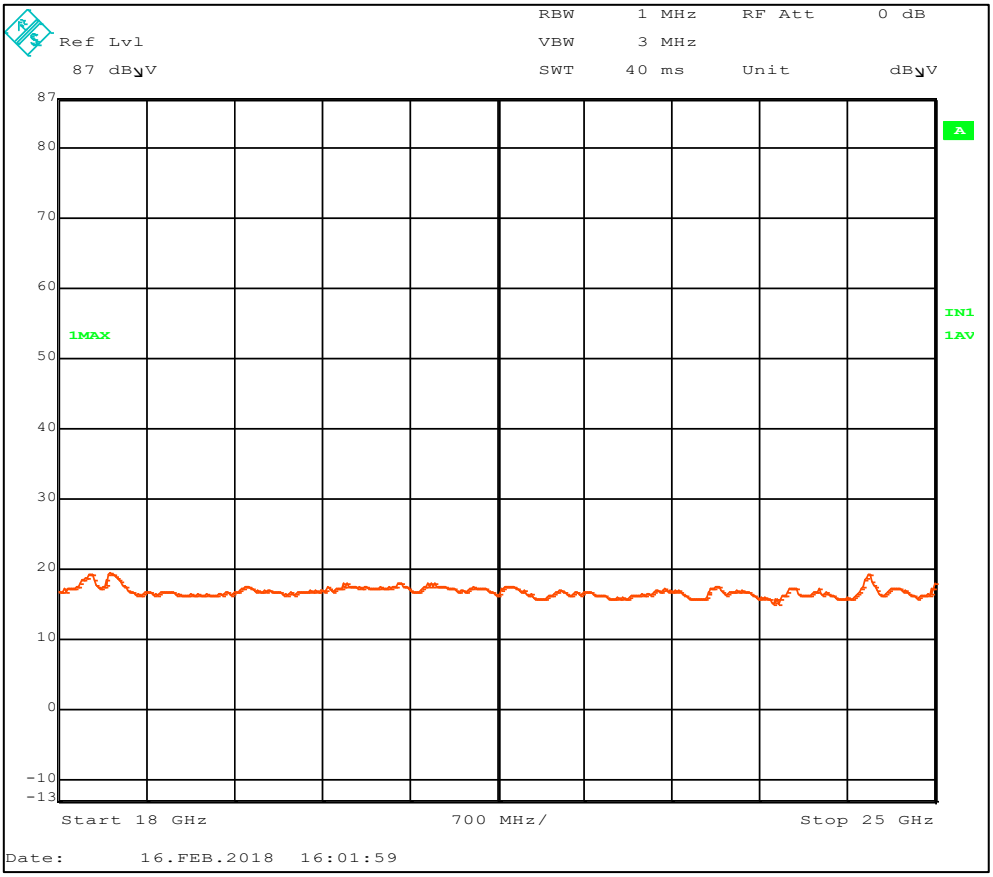


**Figure 25. Radiated emission test results 18 - 25 GHz. Average detector.**

| Average Limit 3 m. | Peak limit 3 m | 3 m / 0.5 m factor | Average Limit 0.5 m. | Peak limit 0.5 m |
|---|---|---|---|---|
| dBµV/m | dBµV/m | dB | dBµV/m | dBµV/m |
| 53.98 | 73.98 | 15.56 dB | 69.54 | 89.54 |

**Table 32. Calculation of limit at 0.5 m.**

| Frequency | AF | Cable loss | Correction factor |
|---|---|---|---|
| GHz | dB/m | dB | dB/m |
| 14 | 37,1 | < 2 | 39.1 |
| 18 | 37,4 | < 2 | 39.4 |
| 18 | 40.3 | < 2 | 42.3 |
| 25 | 40.6 | < 2 | 42.6 |

**Table 33. Correction factors 14 – 25 GHz.**

| Frequency [MHz] | Peak [dBuV/m] | BW [kHz] | Height [cm] | Pol. | Azimuth [deg] | Margin [dB] | Limit [dBuV/m] | Result |
|---|---|---|---|---|---|---|---|---|
| - | - | - | - | - | - | - | 89.54 | PASSED |

**Table 34. Radiated emission test results. 14 - 25 GHz. Peak detector.**

| Frequency [MHz] | Average [dBuV/m] | BW [kHz] | Height [cm] | Pol. | Azimuth [deg] | Margin [dB] | Limit [dBuV/m] | Result |
|---|---|---|---|---|---|---|---|---|
| - | - | - | - | - | - | - | 69.54 | PASSED |

**Table 35. Radiated emission test results 3 - 14 GHz. Average detector.**

### 2.3.3 Test equipment

| Description | Supplier | Model | Tag no. | Cal. due date |
|---|---|---|---|---|
| Antenna Biconical 30 - 300 MHz | ETS-LINDGREN | EMCO 3110B | 13835 | 2019-02-20 |
| Antenna Log Per 0.2 - 1 GHz | ETS-LINDGREN | 3148 | 50083 | 2019-04-14 |
| Antenna Horn | Schwarzbeck | BBHA 9120 D | 20777 | 2019-02-18 |
| Antenna Std gain Horn 12GHz-18GHz | Narda | 639 + 609 | 17219 | NA |
| Antenna Std gain Horn 18 - 26.5 GHz | Narda | 638 + 4608B | 17524 | NA |
| Analyzer 20Hz-26.5GHz | Rohde&Schwarz | ESI | 20763 | 2018-09-05 |

## 2.4 AC Conducted emission

| | |
|---|---|
| **Test specimen** | Dongle DNG002 |
| **Test specification** | 47 CFR Part 15.207 |
| **Test method** | ANSI C63.4:2014 |
| **Frequency range** | 0.15 - 30 MHz |
| **Limits** | 47 CFR Part 15.207 |
| **Comments** | none |
| **Temperature / Humidity** | 22°C / 41%RH |
| **Dates of measurements** | 2018-02-12 |
| **Test personnel** | Søren Søltoft |

### 2.4.1 Test setup

Measurements were performed with the test specimen powered from a USB port in a laptop and powered from a AC/DC adaptor while sending max power with max duty cycle at the middle channel (2449 MHz). In both set up the mains supply was 120 VAC 60 Hz.

See appendix 1 for photo of test set up

### 2.4.2 Test limits

| Frequency (MHz) | Quasi-peak value (dBµV) | Average value (dBµV/m) |
|---|---|---|
| 0.15-0.5 | 66-56* | 56-46* |
| 0.5-5 | 56 | 46 |
| 5-30 | 60 | 50 |

**Table 36. Radiated emission limits**.

Note *=Decreases with the logarithm of the frequency

### 2.4.3 Test results

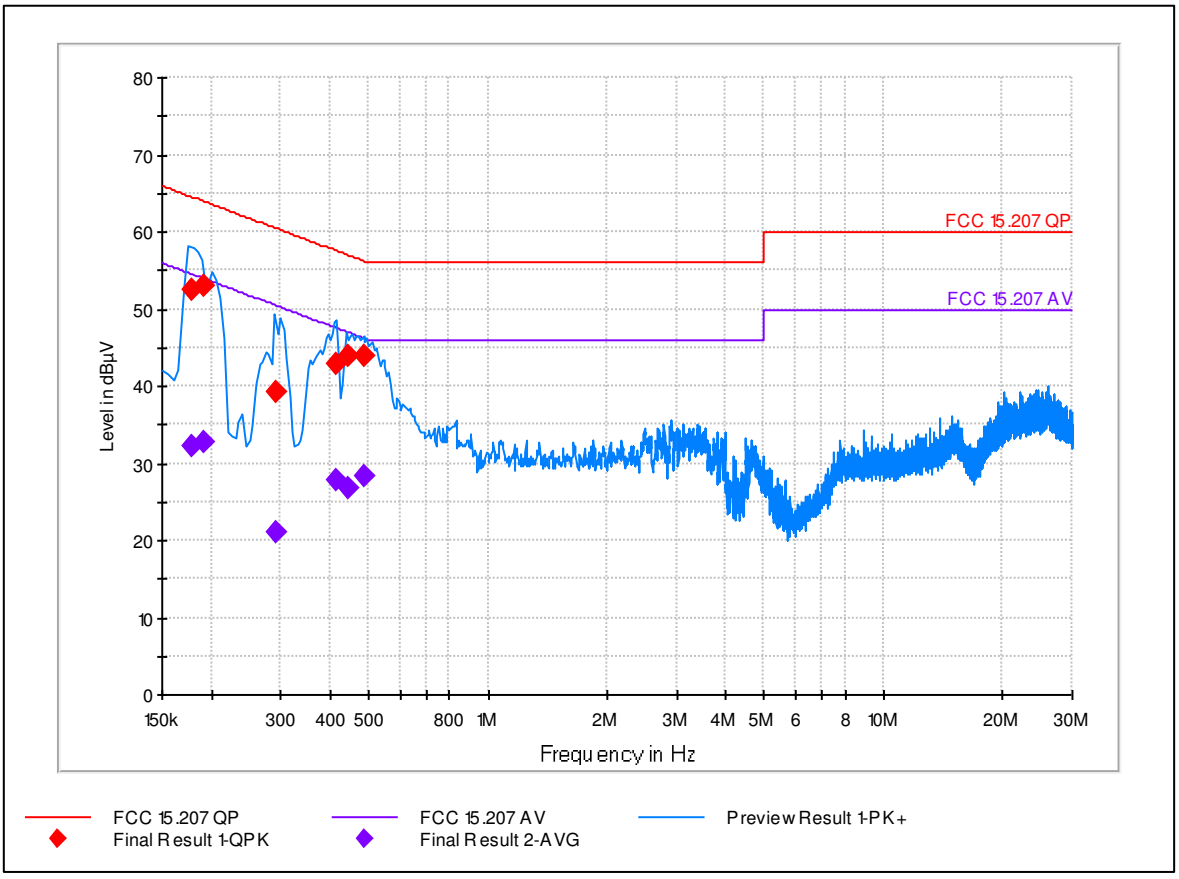


**Figure 26. AC Conducted emission. Powered by laptop**

| Frequency [MHz] | QuasiPeak [dBuV] | BW [kHz] | Line | Margin [dB] | Limit [dBuV] | Result |
|---|---|---|---|---|---|---|
| 0.178900 | 52.5 | 9.000 | L1 | 12.00 | 64.50 | PASSED |
| 0.191200 | 53.1 | 9.000 | N | 10.90 | 64.00 | PASSED |
| 0.290100 | 39.2 | 9.000 | N | 21.30 | 60.50 | PASSED |
| 0.413800 | 42.8 | 9.000 | N | 14.80 | 57.60 | PASSED |
| 0.444800 | 43.8 | 9.000 | N | 13.10 | 57.00 | PASSED |
| 0.488800 | 43.8 | 9.000 | N | 12.40 | 56.20 | PASSED |

**Table 37. AC Conducted emission. Powered by laptop. QuasiPeak detector.**

| Frequency [MHz] | Average [dBuV] | BW [kHz] | Line | Margin [dB] | Limit [dBuV] | Result |
|---|---|---|---|---|---|---|
| 0.178900 | 32.3 | 9.000 | L1 | 22.20 | 54.50 | PASSED |
| 0.191200 | 32.8 | 9.000 | N | 21.20 | 54.00 | PASSED |
| 0.290100 | 21.0 | 9.000 | N | 29.50 | 50.50 | PASSED |
| 0.413800 | 27.7 | 9.000 | N | 19.80 | 47.60 | PASSED |
| 0.444800 | 26.6 | 9.000 | N | 20.30 | 47.00 | PASSED |
| 0.488800 | 28.4 | 9.000 | N | 17.80 | 46.20 | PASSED |

**Table 38. AC Conducted emission. Powered by laptop. Average detector.**

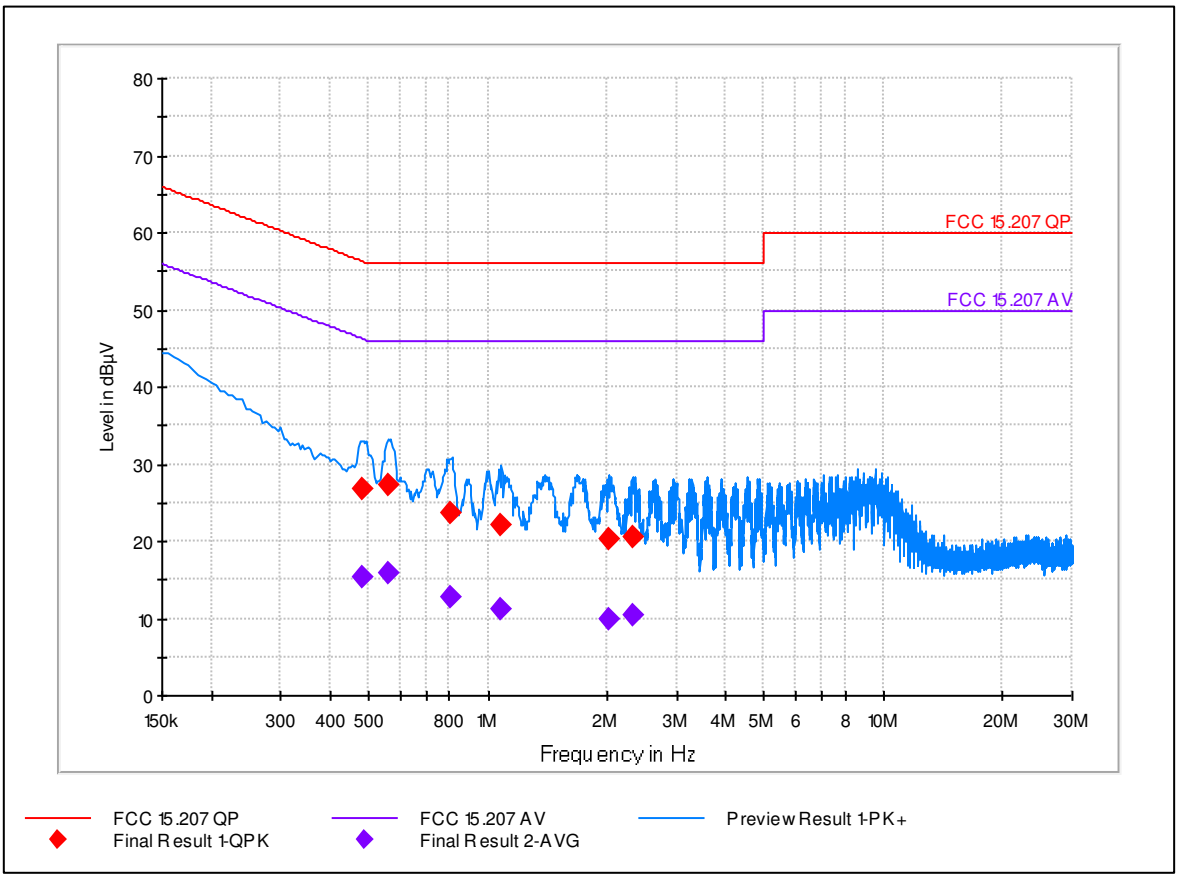


**Figure 27. AC Conducted emission. Powered by AC/DC adaptor.**

| Frequency [MHz] | QuasiPeak [dBuV] | BW [kHz] | Line | Margin [dB] | Limit [dBuV] | Result |
|---|---|---|---|---|---|---|
| 0.480300 | 26.7 | 9.000 | N | 29.60 | 56.30 | PASSED |
| 0.559700 | 27.4 | 9.000 | N | 28.60 | 56.00 | PASSED |
| 0.805100 | 23.7 | 9.000 | N | 32.30 | 56.00 | PASSED |
| 1.074000 | 22.1 | 9.000 | N | 33.90 | 56.00 | PASSED |
| 2.028000 | 20.2 | 9.000 | N | 35.80 | 56.00 | PASSED |
| 2.341600 | 20.5 | 9.000 | N | 35.50 | 56.00 | PASSED |

**Table 39. AC Conducted emission. Powered by AC/DC adaptor. QuasiPeak detector.**

| Frequency [MHz] | Average [dBuV] | BW [kHz] | Line | Margin [dB] | Limit [dBuV] | Result |
|---|---|---|---|---|---|---|
| 0.480300 | 15.3 | 9.000 | N | 31.10 | 46.30 | PASSED |
| 0.559700 | 15.8 | 9.000 | N | 30.20 | 46.00 | PASSED |
| 0.805100 | 12.7 | 9.000 | N | 33.30 | 46.00 | PASSED |
| 1.074000 | 11.2 | 9.000 | N | 34.80 | 46.00 | PASSED |
| 2.028000 | 9.9 | 9.000 | N | 36.10 | 46.00 | PASSED |
| 2.341600 | 10.4 | 9.000 | N | 35.60 | 46.00 | PASSED |

**Table 40. AC Conducted emission. Powered by AC/DC adaptor. Average detector.**

### 2.4.4 Test equipment

| Description | Supplier | Model | Tag no. | Cal. due date |
|---|---|---|---|---|
| V-network Two Line | R&S | ESH3-Z5 | 20682 | 2019-01-22 |
| Receiver EMI Test 20Hz-26.5GHz | Rohde&Schwarz | ESIB 26 | 18880 | 2018-09-05 |

## 2.5 20 dB bandwidth

| | |
|---|---|
| **Test specimen** | Dongle DNG002 |
| **Test specification** | 47 CFR Part 15.215 |
| **Test method** | ANSI C63.10:2013 |
| **Comments** | none |
| **Temperature / Humidity** | 22°C / 37%RH |
| **Dates of measurements** | 2018-01-26 |
| **Test personnel** | Søren Søltoft |

### 2.5.1 Test setup

A measuring distance of 3 m was used during the tests.
The EUT was placed 1.5 m above ground on a non-conductive table.

See appendix 1 for photo of test set up

### 2.5.2 Test results

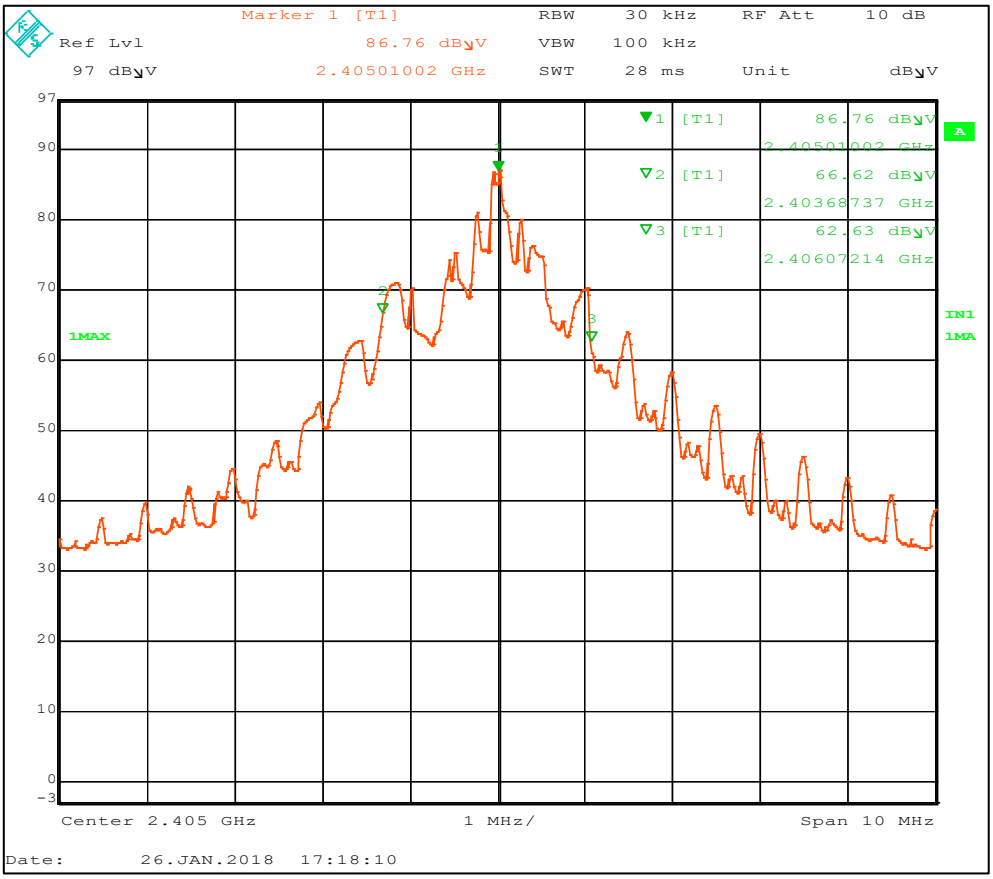


**Figure 28. 20 dB bandwidth at 2405 MHz.**

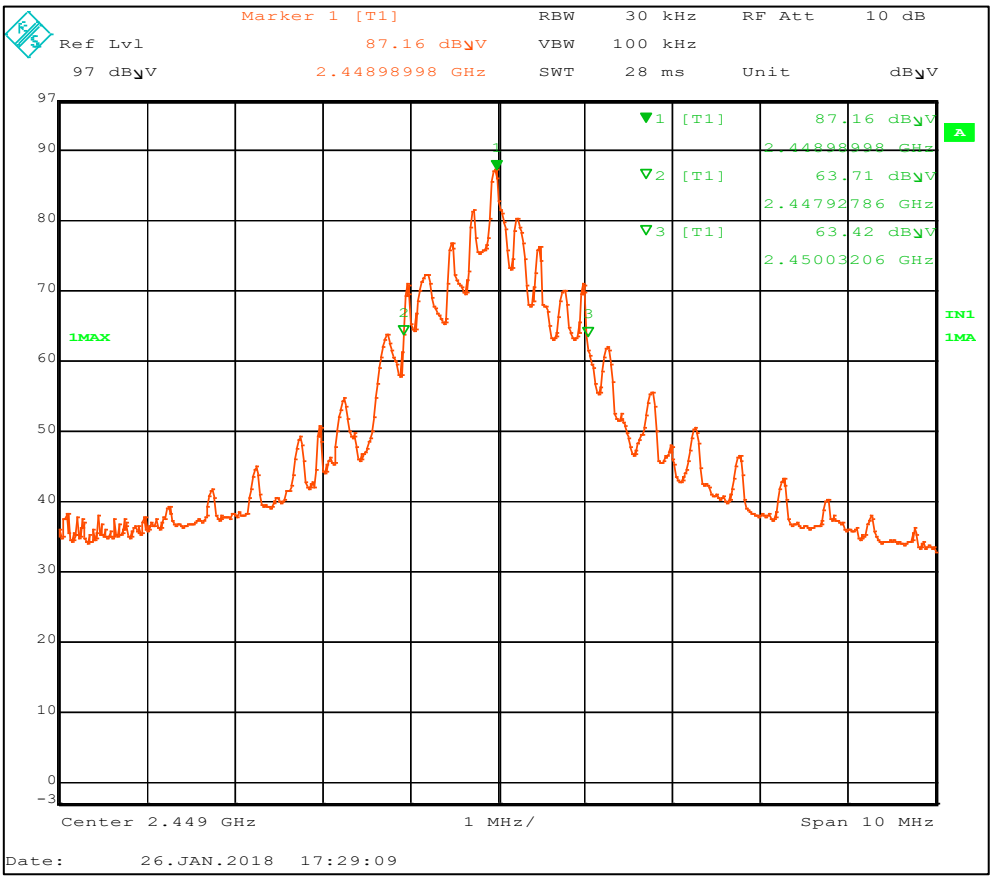


**Figure 29. 20 dB bandwidth at 2449 MHz.**

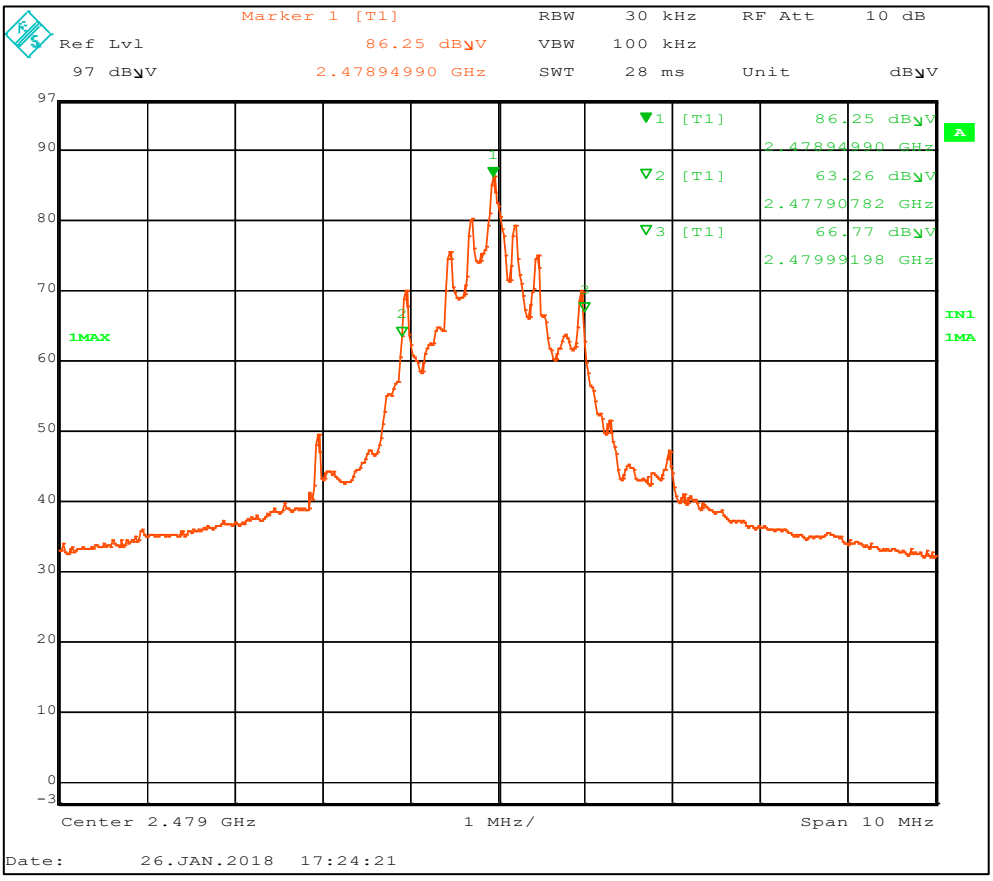


**Figure 30. 20 dB bandwidth at 2479 MHz.**

| Frequency [MHz] | 20 dB Bandwidth [MHz] | Result |
|---|---|---|
| 2405 | 2.38477 | PASSED |
| 2449 | 2.1042 | PASSED |
| 2479 | 2.08416 | PASSED |

**Table 41. 20 dB bandwidth results.**

### 2.5.3 Test equipment

| Description | Supplier | Model | Tag no. | Cal. due date |
|---|---|---|---|---|
| Antenna Horn | Schwarzbeck | BBHA 9120 D | 20777 | 2019-02-18 |
| Analyzer 20Hz-26.5GHz | Rohde&Schwarz | ESI | 20763 | 2018-09-05 |

## 2.6 Occupied bandwidth

| | |
|---|---|
| **Test specimen** | Dongle DNG002 |
| **Test specification** | 47 CFR 2.1049 |
| **Test method** | ANSI C63.10:2013 |
| **Comments** | none |
| **Temperature / Humidity** | 22°C / 37%RH |
| **Dates of measurements** | 2018-01-26 |
| **Test personnel** | Søren Søltoft |

### 2.6.1 Test setup

A measuring distance of 3 m was used during the tests.
The EUT was placed 1.5 m above ground on a non-conductive table.

See appendix 1 for photo of test set up

### 2.6.2 Test results

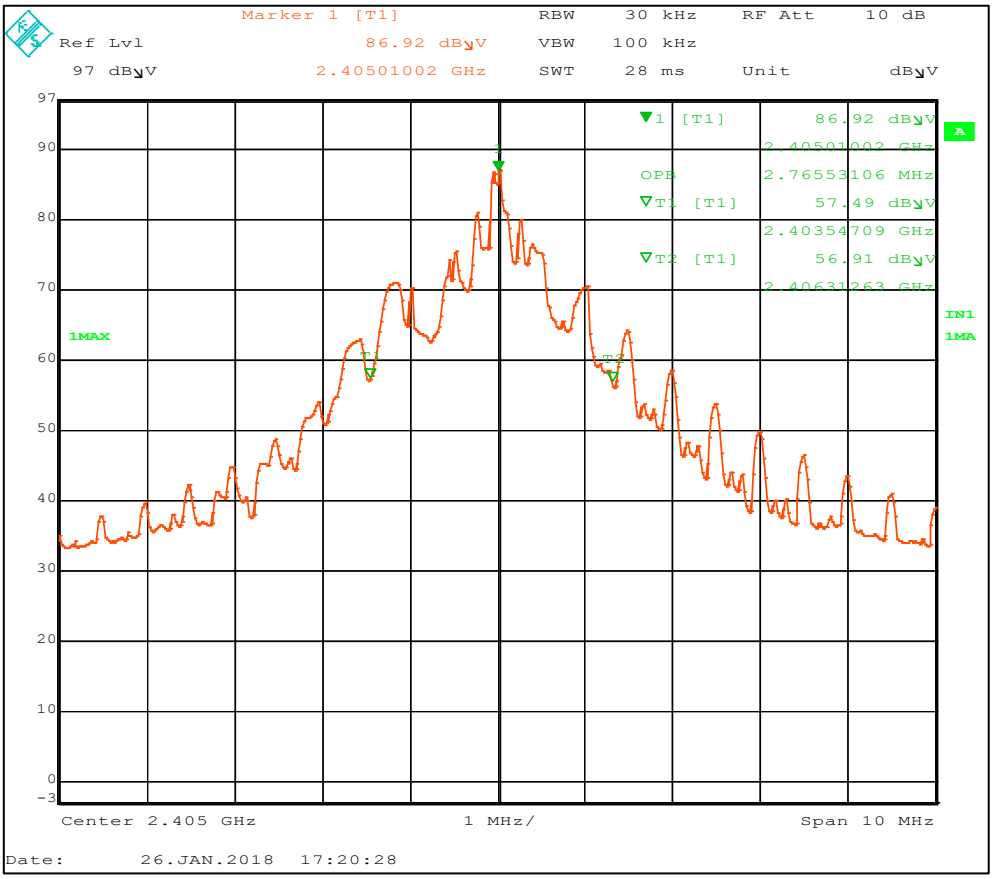


**Figure 31. Occupied bandwidth 99% at 2405 MHz.**

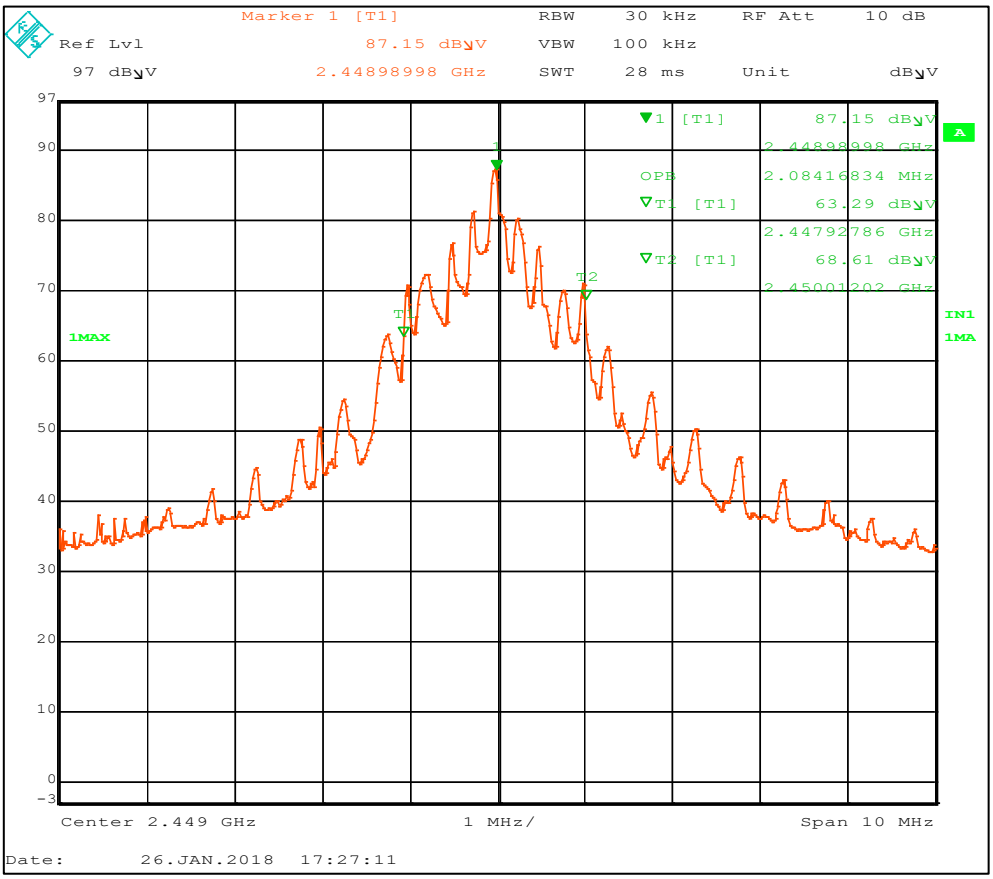


**Figure 32. Occupied bandwidth 99% at 2449 MHz.**

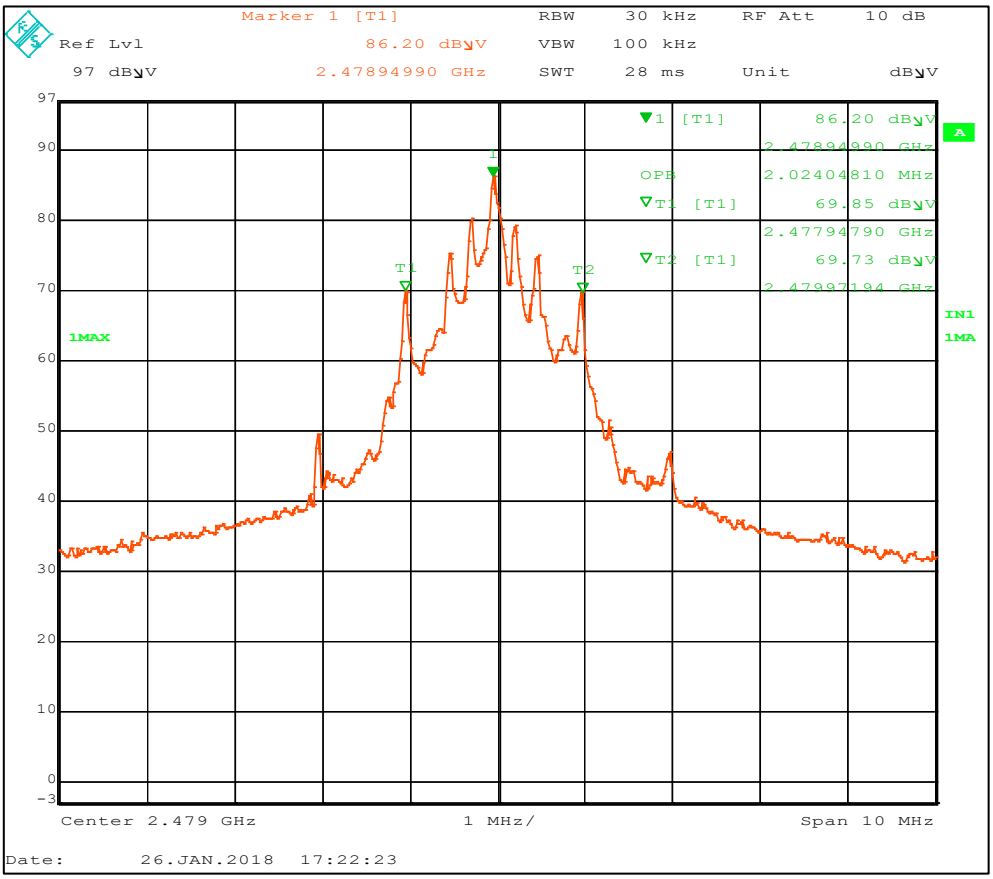


**Figure 33. Occupied bandwidth 99% at 2479 MHz.**

| Frequency [MHz] | Occupied bandwidth 99% [MHz] | Result |
|---|---|---|
| 2405 | 2,76553106 | PASSED |
| 2449 | 2,08416834 | PASSED |
| 2479 | 2,02404810 | PASSED |

**Table 42. 20 dB bandwidth results.**

### 2.6.3 Test equipment

| Description | Supplier | Model | Tag no. | Cal. due date |
|---|---|---|---|---|
| Antenna Horn | Schwarzbeck | BBHA 9120 D | 20777 | 2019-02-18 |
| Analyzer 20Hz-26.5GHz | Rohde&Schwarz | ESI | 20763 | 2018-09-05 |

**Table 43. 20 dB bandwidth test equipment.**

## 2.7 Band edge

| | |
|---|---|
| **Test specimen** | Dongle DNG002 |
| **Test specification** | 47 CFR 2.1049 |
| **Test method** | ANSI C63.10:2013 |
| **Comments** | none |
| **Temperature / Humidity** | 22°C / 37%RH |
| **Dates of measurements** | 2018-01-26 |
| **Test personnel** | Søren Søltoft |

### 2.7.1 Test setup

A measuring distance of 3 m was used during the tests.

The EUT was placed 1.5 m above ground on a non-conductive table.

The turntable, antenna height and antenna polarity were adjusted for maximal radiated emission level.

The graphs are offset with the correction factor to show the maximal level.

See appendix 1 for photo of test set up

According to 15.205 the nearest restricted bands above and below the operational band are 2310 – 2390 MHz and 2483.5 – 2500 MHz. The measurements were made according to ANSI 63.10:2013 clause 6.10.5 Restricted-band band-edge measurements.

Limits according to 15.209.

### 2.7.2 Test results

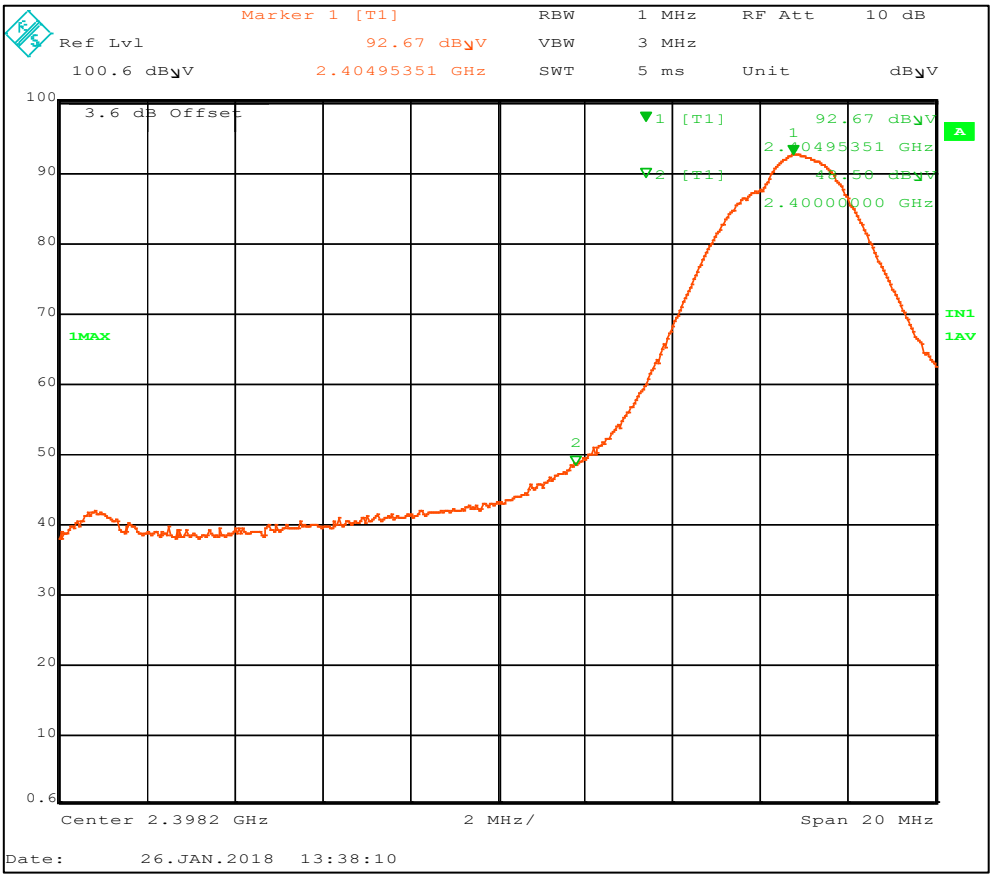


**Figure 34. Band Edge Low channel 2405 MHz. Average detector.**

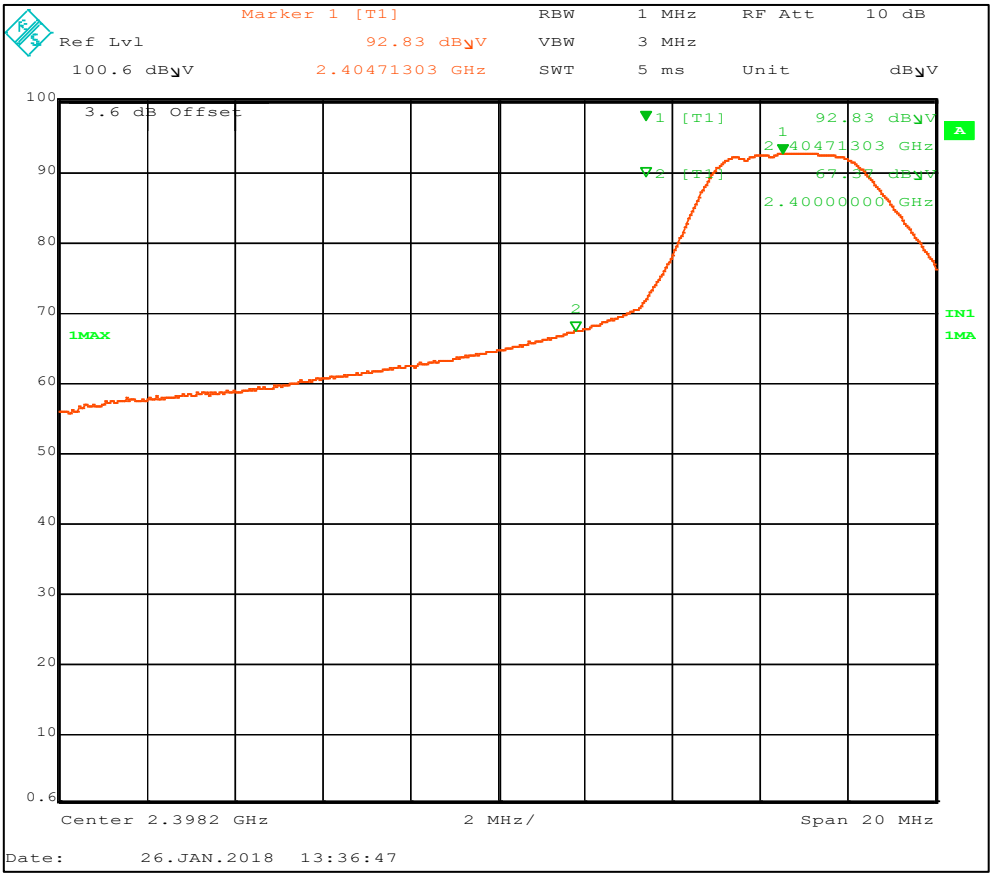


**Figure 35. Band Edge Low channel 2405 MHz. Peak detector.**

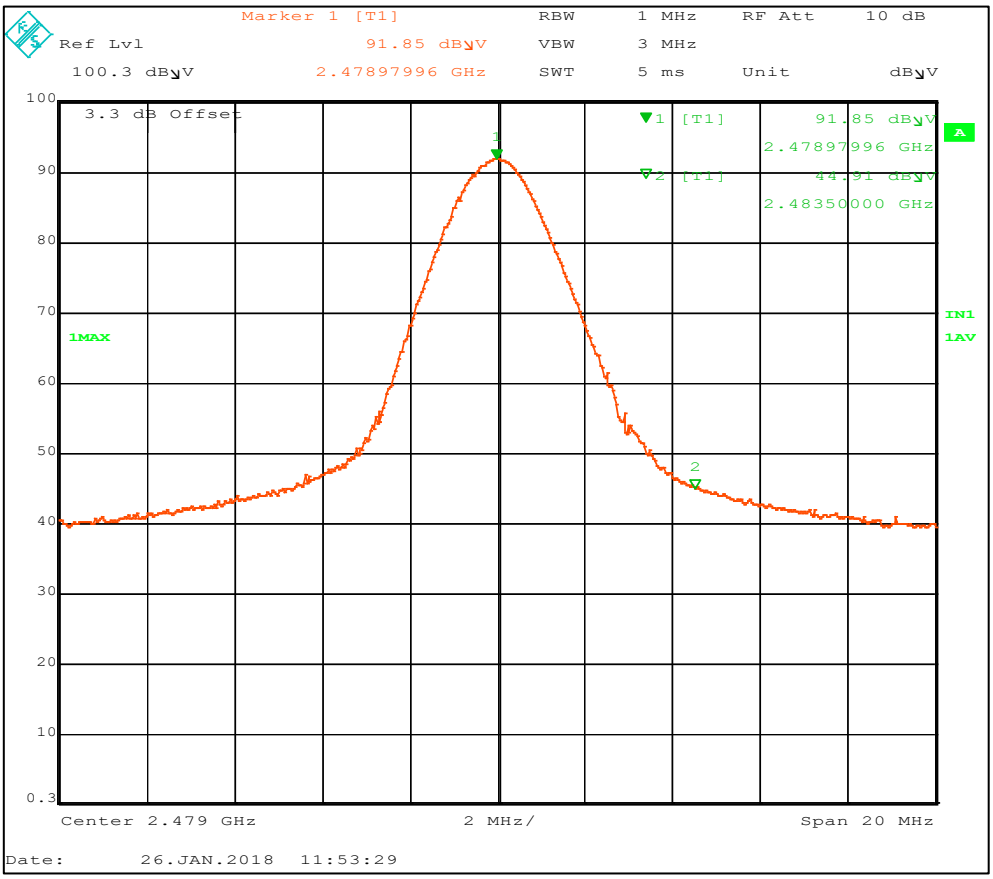


**Figure 36 Band Edge High channel 2479 MHz. Average detector.**

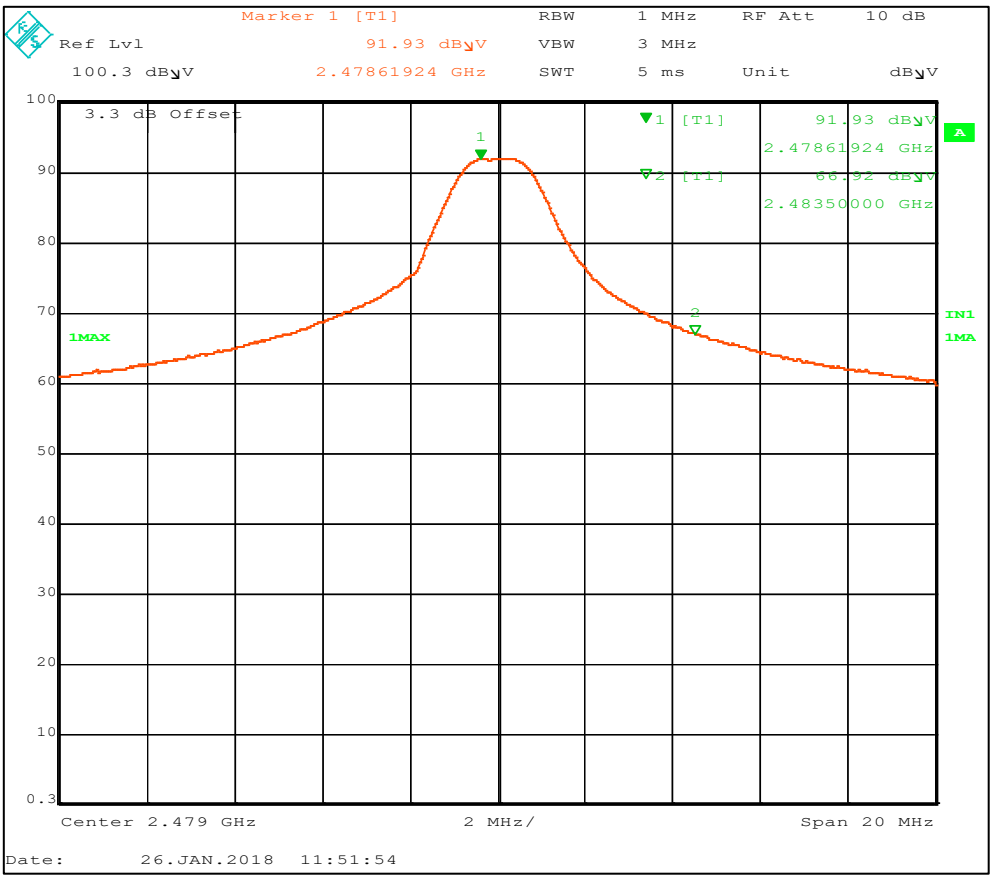


**Figure 37. Band Edge High channel 2479 MHz. Peak detector.**

The fundamental are pulsed, thus the average value is calculated by correcting the Peak detector level with the Duty Cycle Correction Factor found in section 2.1.

| Channel Frequency | Detector | Band-Edge level | Margin | Limit | Result |
|---|---|---|---|---|---|
| [MHz] | | [dBµV/m] | [dB] | [dBµV/m] | |
| 2405 | Average | 40.79 | 13.21 | 54 | PASSED |
| 2405 | Peak | 67.37 | 6.63 | 74 | PASSED |
| 2479 | Average | 40.34 | 13.66 | 54 | PASSED |
| 2479 | Peak | 66.92 | 7.08 | 74 | PASSED |

**Table 44. Band Edge results.**

### 2.7.3 Test equipment

| Description | Supplier | Model | Tag no. | Cal. due date |
|---|---|---|---|---|
| Antenna Horn | Schwarzbeck | BBHA 9120 D | 20777 | 2019-02-18 |
| Analyzer 20Hz-26.5GHz | Rohde & Schwarz | ESI | 20763 | 2018-09-05 |

**Table 45. Band Edge test equipment.**

# 3 MEASURING UNCERTAINTIES

Compliancy evaluation is based on a shared risk principle with respect to the measurement uncertainty.

| | Frequency [MHz] | Polarization | Expanded Uncertainty [dB] (k=2) |
|---|---|---|---|
| Radiated emission | 30 - 200 | Vertical | **4.59** |
| | 200 - 1000 | Vertical | **4.77** |
| | 1000 - 18000 | Vertical | **3.76** |
| | 18000 - 25000 | Vertical | **4.10** |
| | 30 - 200 | Horizontal | **4.57** |
| | 200 - 1000 | Horizontal | **4.86** |
| | 1000 - 18000 | Horizontal | **3.77** |
| | 18000 - 25000 | Horizontal | **4.11** |
| Conducted emission (CISPR 16-4) | 0.01 - 30 | | **3.44** |

# Appendix 1 Photos

**Photo 1. Dongle DNG002**

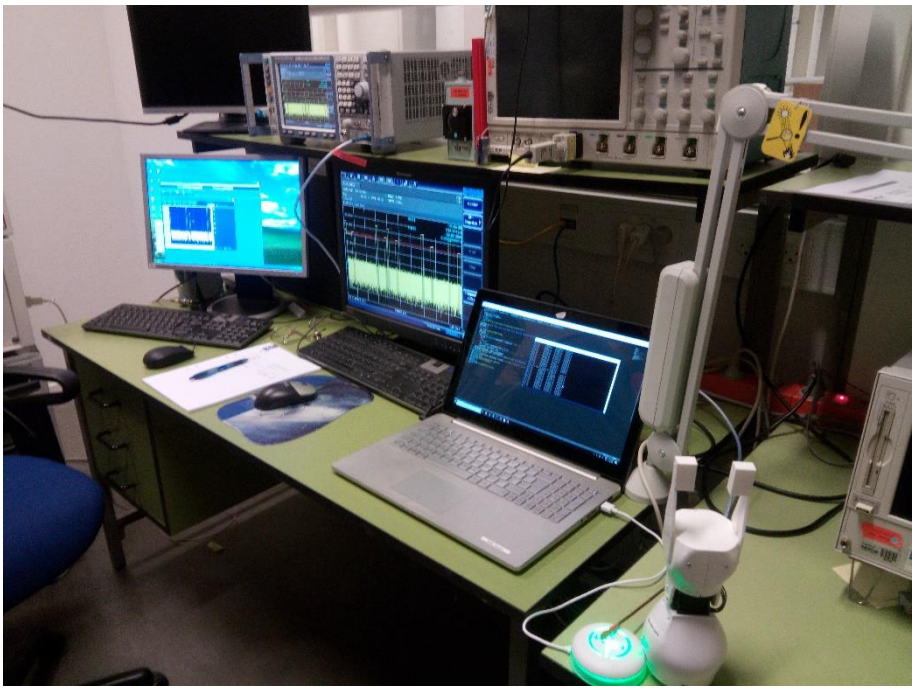

**Photo 2. Duty cycle test set up.**

**Photo 3 - Radiated emission test setup for 30 - 200 MHz.**

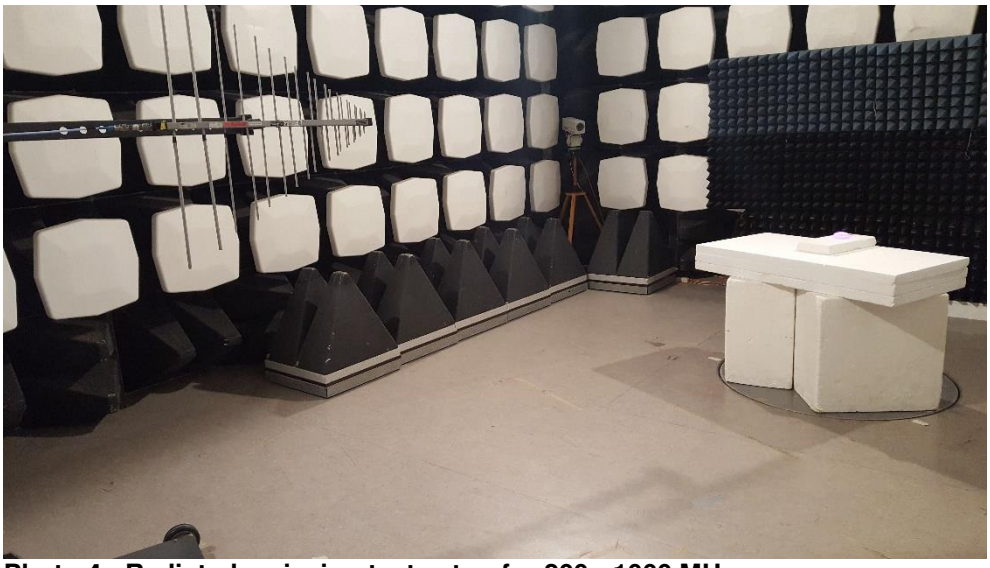

**Photo 4 - Radiated emission test setup for 200 - 1000 MHz.**

**Photo 5 - Radiated emission test setup for 1 – 14 GHz.**

**Photo 6. Radiated emission test setup for 14 – 25 GHz. With ruler indicating distance.**

**Photo 7. Vertical orientation**

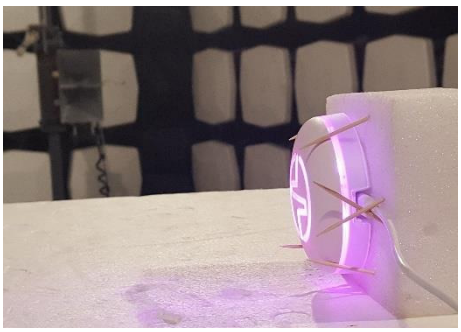

**Photo 8. Vertical – 90 deg. orientation**

**Photo 9. Horizontal orientation.**

**Photo 10. AC Conducted emission test set up. Powered by laptop**

**Photo 11. AC Conducted emission test set up. Powered by AC/DC adaptor**